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THE TRANSFORMED CATENARY AS A FIGURE FOR ARCHES IN STONE OR METAL.*

By WILLIAM HY. BOOTH, of Flixton, near Manchester.

Written for Van Nostrand's Magazine.

The mathematical curve known as the catenary is the curve formed by a chain, or cord of uniform section throughout, loaded only with its own weight.

The transformed catenary, as used for the figure of an arch, is derived from the common catenary by parallel projection, and Rankine thus describes its peculiar properties as distinguished from the common catenary:

"The common catenary is the curve of equilibrium for a chain supporting a load which, whether arising from its own weight or from other weights also, is proportional upon any given arc AB of the chain to the area enclosed between that arc, the two ordinates AO, BX, and the directrix OX, which is at a depth m below the vertex, the *intensity* of the load at any point B being proportional to the ordinate y=BX."

Rankine then goes on to say that the load on the chain may be assumed to consist of an uniformly thick sheet of a homogeneous substance which, upon the arc AB would have the dimensions AO XB, and, calling the weight of an unit of area $=w$, he gives the horizonal tension at A$=wm^2$, m being the parameter of the curve =OA. Looking at Fig. 1, and supposing a curve ab made so that, whilst the horizontal abscissae are kept the same, the vertical ordinates are all proportionately altered, so that OA : Oa : : XB : Xb, and denoting the vertical distance Oa by y_0, and Xb by y_1, and putting y for XB we get $m : y_0 : : y : y^1$.

Then, ender these suppositions, Rankine defines the transformed catenary to be the form of equilibrium for a chain, so loaded that the weight upon any arc ab is proportional to the area OabX; the intensity of load at any point b being proportionate to the ordinate Xb, all the vertical forces thus being altered in the ratio $y_0 : m$, and the horizontal forces remaining the same. The following equations are then given, upon which calculations may be based:

H the horizontal tension at $a=wm^2$, as in the catenary.

Intensity of load at

$$b=wy^1=\frac{wy_0}{2}\left(e^{\frac{x}{m}}+e^{-\frac{x}{m}}\right)$$

x being the abscissa OX and $e^{\frac{x}{m}}$ and $e^{-\frac{x}{m}}$ being the Naperian anti-logarithm of $\frac{x}{m}$ and the reciprocal which require a table of hyperbolic logarithms in using; but the following formula may be used instead:

* The calculations in this paper are not absolutely accurate, but sufficiently so for practical purposes.

$$e^{\frac{x}{m}} = 10^{.4343\frac{x}{m}} \text{ and } e^{-\frac{x}{m}} = \frac{1}{10^{.4343\frac{x}{m}}}$$

The load between

$$a \text{ and } b = \mathrm{P} = \frac{wmy_0}{2}\left(e^{\frac{x}{m}} - e^{-\frac{x}{m}}\right)$$

The tension at $b = \sqrt{\mathrm{P}^2 + \mathrm{H}^2}$

The principal use of the transformed catenary, says Rankine, is as a figure for arches, the curve being inverted, and tensions becoming thrusts. Such an arch is suited to sustain vertical loads of an intensity proportionate to the vertical ordinate at each point, the intrados being formed to the curve of equilibrium, and the extrados of the arch may be either a horizontal line or another transformed catenary. If horizonal, it necessarily coincides with the directrix OX. It is very certain that the majority of arches, in stone especially, that have ever been constructed are not of the form of an arch of equilibrium. Circular arcs have almost wholly been employed for such arches as do not approximate to the hydrostatic arch, *i. e.*, elliptical arches. No doubt the thickness of the arch-rings of most arches is so great that a curve of equilibrium may be drawn within the ring, and at a safe distance within it, probably within the middle third of the thickness, as recommended by Rankine, *i. e.*, of course for arches not exceeding 120°. It is by no means, however, to be taken for granted, even if the curve of equilibrium do fall outside the theoretical safe limit, that "the stability of such arches is either now precarious, or must have been precarious while the mortar was fresh," as Rankine has stated. If arches consisted only of the arch-ring, pure and simple, this would no doubt hold good, but before the centering is struck it is usual to build in the backing, oftentimes, too, level with the crown of the arch, or to fill in the spandrils with a sufficiency of walling well bound in with the arch-ring proper, thus preventing any movement of the arch, either towards collapse inwards or bursting outwards; and an arch thus well built would stand without the arch-ring proper, which is but a portion of a well-connected whole, and may be said to be the arch proper by courtesy alone.

It is, however, always more satisfactory to the engineer to know that the structures he designs contain within themselves the elements of stability apart from the stability which springs from the faithful execution of the work of the mason or bricklayer, or the use of the best metal; and it is probable that the use of the inverted transformed catenary would have been more common if the mode of making the necessary calculations had been explained by Rankine more clearly than has been the case. It appears to the writer that the work of Rankine has been to grasp the natural laws bearing on the general subject of engineering, and formulate the same without making any attempt to elucidate the valuable information for the benefit of the more immediately practical man. Rankine's works want translating into a simpler form for daily use; the absolutely needful grain requires extracting from the mathematical envelope which, however interesting to the mere student of form, is worthless as an aid for the majority of our constructing engineers.

Let us then, by taking an example, endeavor to show how the transformed catenary may be found for a given arch. In practice, when an arch is to be built, it is probable that two levels would be given from which little or no deviation could be allowed.. These two would be the roadway surface over the crown of the arch and the points of springing. To determine a curve a third point would be required—the vertex of the arch, *i. e.*, the distance of the intrados at the crown from the road surface or Oa. (Fig. 1.) Knowing these three points we should require, in order to find the form of the transformed catenary, the modulus, or parameter m, of the catenarian curve from which our arch is to be transformed by alteration of the vertical ordinates.

Calling, as before, $y_0 = \mathrm{O}a$, the depth of crown below the horizonal ox, and y_1 the ordinate, Xb at the point of support b distant $x = \mathrm{OX} =$ the half span of the bridge from the vertex a, we have,

$$\mathrm{M} = \frac{\mathrm{X}}{\text{hyp. log.}\left(\frac{y_1}{y_0} + \sqrt{\frac{y_1^2}{y_0^2} - 1}\right.} \quad . \quad (1)$$

and knowing the modulus m, we may then calculate readily our different stresses, &c.

Let us take as our data a stone arch of

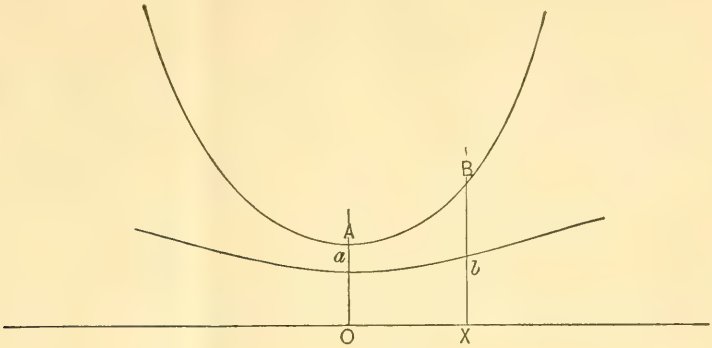


Fig. 1

180 feet span; then half span $=x_1=90$. Let the height Xb (Fig. 1) be assumed to be 42 feet; then, $y_1=42$.

Taking, then, a thickness of 6 feet for the arch-ring, ballasting and roadway, we get $42-6=36$ feet as the rise of the arch, and y_0 is thus 6. Tabulating these data, we have,

$$x_1=90=\text{OX}, \quad \text{(Fig. 1.)}$$
$$y_1=42=b\text{X}, \quad \text{"}$$
$$y_0=\ 6=\text{O}a, \quad \text{"}$$

and we have to find $m=$OA (Fig. 1) from the formula (1), in which, substituting the numerical values of the signs, we have

$$\text{M}=\frac{90}{\text{hyp. log.}\left(\frac{42}{6}+\sqrt{\frac{1764}{36}-\frac{36}{36}}\right)}$$
$$=\frac{90}{(\text{hyp. log. }(7+6.9282)}$$
$$=\frac{90}{\text{hyp. log. }13.9282}$$

The hyp. log. of 13.9282 may be found from the common logarithm, which is 1.143895, in the usual way. It will be found to be 2.6339; substituting this in the equation gives $m=\frac{90}{2.6339}=34.16$ ft. Thus, without any previous knowledge of the catenarian curve, the modulus may be found by simply knowing the span of an arch, the height from the springing of the intrados to the roadway, and the depth of arch-ring and loading at the crown, the formula (1) giving the result without difficulty.

So far, however, we have three points only in the intrados, namely, the crown and the two springings; the curve of the arch requires calculating, and this must be done by finding the vertical ordinates y, &c., corresponding to their respective abscissae x, &c., which latter may be fixed upon at will.

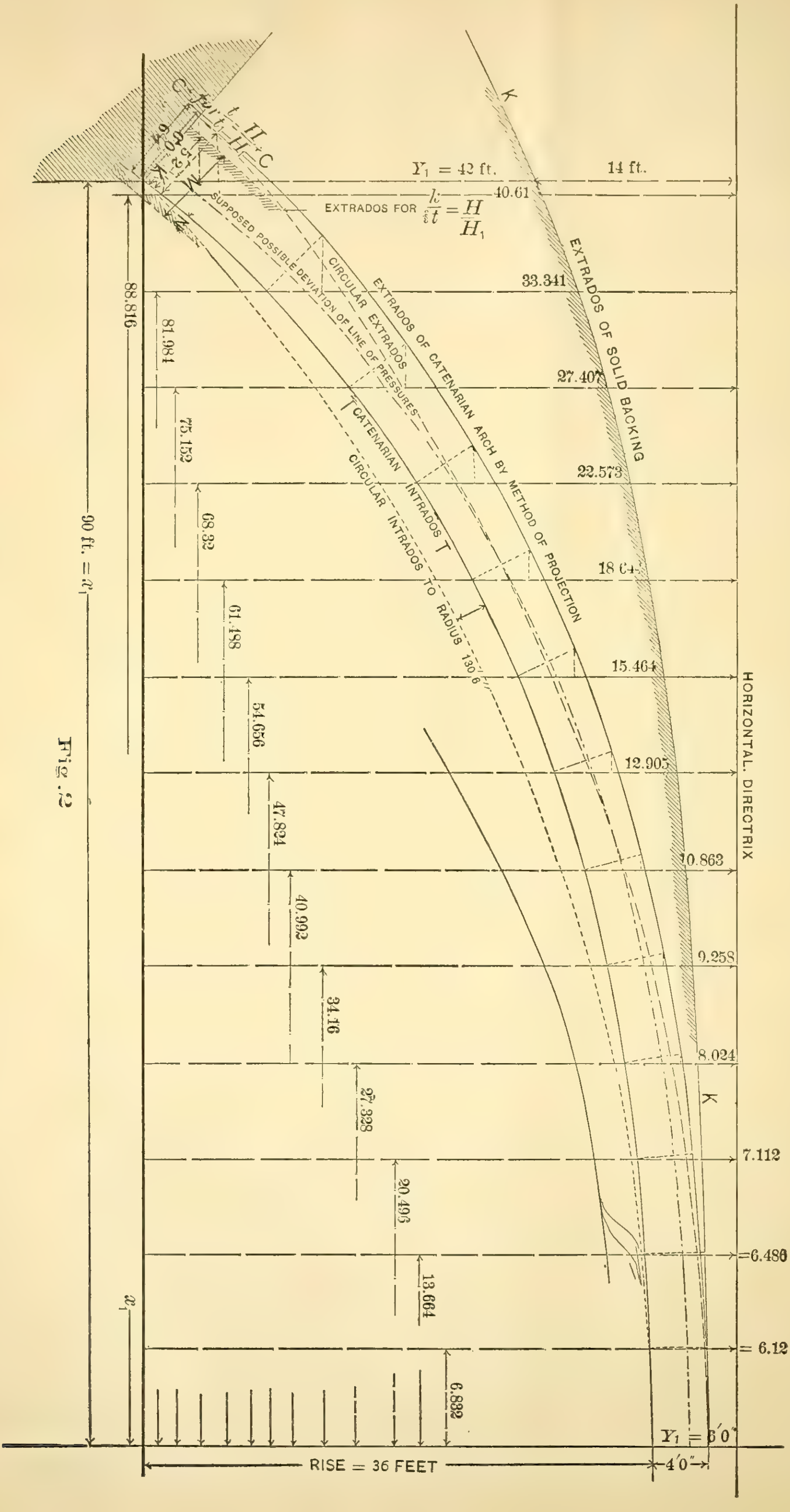
The formula for calculating the vertical ordinate y for any horizontal distance x from the crown is

$y=\frac{y_0}{2}\left(e^{\frac{x}{m}}+e^{-\frac{x}{m}}\right)$ the quantities $e^{\frac{x}{m}}$ and $e^{-\frac{x}{m}}$ having the values already stated.

By fixing certain values to the quantity $\frac{x}{m}$ a table may be readily calculated from which the corresponding ordinates y may be found for any catenarian curve whatsoever, thus saving the labor of constantly working out the last equation. Such a table Rankine gives for values of $\frac{x}{m}$ from 0, which corresponds with the vertex to 3.0, beyond which few arches, in stone at least, are found to extend. A similar table, calculated by the writer, is given herewith, extending to $\frac{x}{m}=4$

To calculate the vertical ordinates for plotting upon the drawing of the arch (Fig. 2) set down any values of $\frac{x}{m}$ in a column as below.

In the next column from the known value of $m=34.16$, place the value of x, which set off on the drawing, as shown from the middle ordinate y_0. In the third column, headed $\frac{y}{y_0}$, place these values as found from Table I., and y_0 being chosen in this case as 6 feet, set down in the fourth column the tabular number



$Y_1 = 42$ ft.
14 ft.
40.61
EXTRADOS FOR $\frac{k}{t} = \frac{H}{H_1}$
SUPPOSED POSSIBLE DEVIATION OF LINE OF PRESSURES
CIRCULAR EXTRADOS
EXTRADOS OF CATENARIAN ARCH BY METHOD OF PROJECTION
EXTRADOS OF SOLID BACKING
CATENARIAN INTRADOS
CIRCULAR INTRADOS TO RADIUS 130.6
HORIZONTAL DIRECTRIX
33.341
27.407
22.573
15.464
12.905
10.863
9.258
8.024
7.112
=6.480
= 6.12
88.816
81.984
75.152
68.32
61.488
54.656
47.824
40.992
34.16
27.328
20.496
13.664
6.832
90 ft. $= x_1$
x_1
$Y_1 = 6'0''$
RISE = 36 FEET
4′0″
K
T

Fig. 2

from the third column multiplied by 6. The results will then be the values of the vertical ordinates which are then to be set off on the drawing at their respective distances x from the vertex.

TABLE II.

DATA FOR CASE UNDER CONSIDERATION.

$m=34.16. \quad y_0=6$

Abscissæ.				Ordinates.		
If $\frac{x}{m}$ = .2	then x =	6.832	and $\frac{y}{y_0}$ =	1.02	∴ y =	6.12
" .4	"	13.664	"	1.081	"	6.486
" .6	"	20.496	"	1.1854	"	7.1124
" .8	"	27.328	"	1.3373	"	8.0238
" 1.0	"	34.16	"	1.5431	"	9.2586
" 1.2	"	40.992	"	1.8106	"	10.8636
" 1.4	"	47.824	"	2.1509	"	12.9054
" 1.6	"	54.656	"	2.5774	"	15.4644
" 1.8	"	61.488	"	3.1074	"	18.6444
" 2.0	"	68.32	"	3.7622	"	22.5732
" 2.2	"	75.152	"	4.5679	"	27.4074
" 2.4	"	81.984	"	5.5569	"	33.3414
" 2.6	"	88.816	"	6.769	"	40.614
Half span	=	90.000	"	7.000	"	42.000

The correctness of the calculations and plotting is readily judged by the accuracy with which the curve drawn through the points thus formed comes in with the originally chosen ordinate y_1 at the springing. If the curve does not come in fair it is proof of error in either the plotting or the calculations, which must be corrected.

If we assume that the thickness of the arch stones at the crown is to be 4 feet, there would remain a depth of 2 feet below the directrix or road surface which may be occupied by walling merely. As a matter of fact, in practice such a slight depth as this would require to be wholly solid, as the material for the roadbed would need at least this depth; but the writer purposely chose the dimension Oa (Fig. 1) as only 6 feet, in order that this point in designing might be made clearer, and for a further consideration afterwards to appear. If the whole thickness of crown, 6 feet, was filled solid with masonry, it would be necessary to fill the whole of the spandrills of the arch also solid to the road surface, in order that the weight of every portion of the area aOXb (Fig. 1) might be properly proportioned to the portion of the arch sustaining it; and, therefore, to comply with these conditions, we will assume that the arch crown is solid for a thickness of 4 feet only, the remainder being walled. In order, then, that the arch may every where be subjected to the correct loading, we must set off downwards on each ordinate yy, &c., a distance equal to $\frac{4}{6}$ of the distance from the directrix or road surface to the intrados of the arch. A curve KK drawn through the points thus found is then the boundary up to which the solid backing of the arch must be carried, the upper third of the ordinates being, as at the crown, partially filled by a series of walls, upon which rests the roadway, which in the present case we will suppose to be of no weight to suit our otherwise incorrectly chosen dimensions. It may be added here that to correct the fault of too small a thickness at the crown, a higher roadway might have been taken, or a less rise to the arch, so that Oa should have been, say, 10 feet. If the roadway had been raised at the crown the extrados of the arch, in place of coinciding with the directrix as now chosen, might have been, as Rankine states, "another transformed catenary having the same directrix." Such, in fact is the extrados of the solid backing in the figure (Fig. 2).

Assuming 120 lbs. per cube foot as the average weight of our arch and load as arranged, $\frac{2}{3}$ solid and $\frac{1}{3}$ in walls and voids, we may calculate the thrust at the crown H, and springing H_1. These are, by definition, the same as in the catenary of origin, namely, $H=wm^2$.

$$m^2=34.16^2=1166.9,$$
$$\therefore \quad H=140028 \text{ lbs.}$$

The thrust along the arch at the springing can only be known when the load P on the half arch is known.

$$P=\frac{wmy_0}{2}\left(e^{\frac{x}{m}}-e^{-\frac{x}{m}}\right)$$

Now x at the springing = half the span or 90 feet. Therefore

$$P=\frac{120\times34.16\times6}{2}\left(e^{\frac{x}{m}}-e^{-\frac{x}{m}}\right)$$

$$e^{\frac{x}{m}}=10^{.4343\frac{x}{m}}$$

$$\text{horz. } 10=1 \therefore e^{\frac{x}{m}}=\frac{90\times.4343}{34.16}=1.144$$

Then

anti log. of 1.144=13.932 and $\frac{1}{13.932}$ the reciprocal =.072.

$$\therefore \left(e^{\frac{x}{m}} - e^{-\frac{x}{m}} =\right) (13.932 - .072) = 13.86$$

$$\therefore \quad P = 12297.6 \text{ lbs.} \times 13.86 = 170445.$$

Then the thrust along the arch at the springing

$$= H_1 = \sqrt{P^2 + H^2}$$

Log. $P^2 = .46316$, &c. $\therefore$ $P^2 = 29050$, &c.
Log. $H^2 = .292429$, &c. $\therefore$ $H^2 = 19608$, &c.
Sum, 48658, &c.

and $\sqrt{48658, \&c.} = 220590 = H_1$

Thus $\left.\begin{matrix} H_1 = 220590 \\ H^1 = 140028 \end{matrix}\right\}$ pounds compressive strain on each foot of breadth of arch, or 11669 and 18382 lbs. per inch of breadth.

With a factor of safety 10, and assuming 10,000 as crushing strain, the above is equivalent to about $11\frac{1}{2}$ and $18\frac{1}{2}$ inches respectively for depth of arch-ring as a minimum.

The least thickness, according to the empirical formula, usually adopted for keystone dimensions, is $t = \sqrt{.12}\,R$ and this is greater than the mere crushing strain. If we assume that the arch is circular the radius of the crown R will be with a chord of 180 feet$=2x$, and a versed sine or rise of 36 feet$=v$, thus expressed,

$$R = \tfrac{1}{2}\left(\frac{x^2}{v} + v\right) = 130 \text{ ft. } 6 \text{ in.}$$

Under this assumption the depth t of the keystone $\sqrt{.12R}$ would be $\sqrt{15.66}$, or 3ft. $10\frac{3}{4}$in.—practically 4 feet. Actually, however, the crown radius of the catenarian arch is greater than the radius of a circular arch of same span and rise as shown in Fig. 2 where the circular arch is in dotted line.

Taking the catenarian crown radius as $\frac{m^2}{y_0}$ we have $R=194.5$, and t, therefore, becomes $t=\sqrt{23.34}$, or say 4ft. 10in., being almost exactly five times the calculated strength to resist crushing, and the springing depth on the same assumption must be $18\frac{1}{2}$in.$\times 5$, or 7ft. 8in. To ascertain if the line of pressures falls within the middle third of the thickness of the arch-ring we take $\frac{2}{3}$ of the depth of crown$=38\frac{2}{3}$in., and $K=\frac{1}{3}$ the arch thickness at the springing. Then

$$\frac{K}{38\frac{2}{3}} = \frac{\text{Thrust at crown}}{\text{Thrust at springing}} = .6363 \quad \therefore \quad K = 24\tfrac{1}{2} \text{ inches}, \qquad (3)$$

which shows that the depth of arch-ring at the springing must be 6 feet only, and the factor of safety is therefore less than at the crown but still largely in excess. The condition is therefore fulfilled, and the arch stable with these dimensions.*

It is clear, by inspection of Fig. 2, that at the point a a circular arch falls within the true curve, and though this is not apparently the case to an unsafe extent, it appears to show at least a tendency to crush inwards at the haunches. It should not, however, be overlooked that as all arches on settling, after removal of the centerings, come down somewhat at the crown, and that in practice the extreme flatness of the true curve would be well modified, the form of the centerings lying somewhere between the true curve and the circular arc, so that after settlement has taken place the arch may be correct.

It would appear, also, that when the circular form is adhered to, the spandril filling may be lighter than for the ideal arch, so that the flatness about the haunches (at a) may be compensated by a corresponding reduction in the intensity of the pressure, and this may readily be accomplished by the thinning of the walls.

In the case illustrated with the dimensions as purposely chosen to extend this point, the circular arch might, with advantage, have been substituted for the catenary by reason of the fact already pointed out, that the thickness of the arch crown is so nearly equal to the depth y_0 of the crown ordinate, that, with the arch-ring and the roadway together, the whole depth y_0 would be solid material, and to keep up the conditions of equilibrium the whole spandril filling

* If it is specially desired to adhere to keystone depths exactly proportionate to thrusts along the rib, the value of K might be found as per formula (3) and if it does not come in within the middle third of the thickness of the arch ring, the f curve of the intrados may be modified accordingly. What is necessary under the requirement of the middle third theory is, however, merely that K should exceed a third of the springing thickness and be less than $\frac{2}{3}$ the same.

It will be noticeable also in Fig. 2 that the familiar method of ascertaining the form of extrados by projection of the crown thickness upon the normal gives a thickness of arch ring which falls between the two results obtained by the formula

$$\frac{t}{t_1} = \frac{H}{H_1} \text{ and } \frac{K}{\frac{2}{3}t} = \frac{H}{H_1}$$

would require also to be solid up to the horizontal line or directrix. With such dimensions the catenarian form could thus not be strictly adhered to without an unnecessary weight of masonry in the spandril filling. With an exactly equilibrated arch in which an ample depth of keystone has been allowed by the empirical formula already quoted it would seem that the true science of contraction would not demand any solid backing whatever, a mere spandril filling of light wall masonry being alone requisite to carry the horizontal roadway. In Fig. 2 the crown thickness is drawn 4 feet only. The equal strength for the springing will thus be $4 \times \frac{22}{14} = 6.3$ft., but the formula for K brings out $t_1 = 5$ft. 2in. only.

To illustrate the transformed catenarian arch under other conditions, let the dimensions be

Half span $= x_1 =$ say, 80 feet,
Rise of arch $=$ " 30 "

Depth of crown below directrix

$= 16\text{ft.} = y_0$,

Then $y_1 = 30 + 16 \quad = 46\text{ft.}$

Finding the modulus m we have by the formula (1),

$$\frac{80}{\text{hyp. log.}\left(\frac{46}{16} + \sqrt{\frac{2116.}{256} - \frac{256}{256}}\right.}$$
$$= \frac{80}{\text{hyp. log. } 5.57} = \left.\frac{80}{1.7174}\right) = 46.58 \text{ ft.}$$

Then as in previous example by the use of Table I.,

If $\frac{x}{m}$ = .2	then x=	9.316	and $\frac{y}{y_0}$ =	1.02	∴ y=16.32
" .4	"	18.632	"	1.081	" 18.296
" .6	"	27.948	"	1.1854	" 17.946
" .8	"	37.264	"	1.3373	" 21.3968
" 1.0	"	46.58	"	1.5431	" 24.6896
" 1.2	"	55.896	"	1.8106	" 28.9696
" 1.4	"	65.212	"	2.1509	" 34.4144
" 1.6	"	74.528	"	2.5774	" 41.2384
"	"	80.000	"	2.875	" 46.000

Assuming an average of 50 lbs. per cubic foot for the whole area of land between the intrados and the roadway, we obtain the thrust at crown $H = wm^2 =$ 108484 lbs. per foot of breadth, or 9040 lbs. per inch of breadth of arch.

The load on half arch per foot of breadth

$$= P = \frac{mwy_0}{2}\left(e^{\frac{x}{m}} - e^{-\frac{x}{m}}\right)$$

$\frac{x}{m} = 1.717.$ Hyp. anti. log. $1.717 = 5.57.$

Recip. $5.57 = .1795$ and $5.57 - .1795$
$= 5.3905$

$\therefore\ P = 18732 \times 5.3905 = 100975.$

The thrust along arch at springing $= H_1$ $= \sqrt{P^2 + H^2} = 148200$ or 12350 lbs. per inch of breadth.

With these stresses at a working stress of 1000 lbs. per square inch, the arch stones would require a depth of 9 inches and 12½ inches at crown and at springing respectively.

The radius at crown is $\frac{m^2}{y_0} = 135.6$ feet, the radius of a similar circular arch being 121.6 ft.

Taking the longest radius, the thickness of crown by empirical rule is $t = \sqrt{.12 \times 135.6}$, or 4 feet, and t_1 at the springing to be equally strong $= 4 \times \frac{H_1}{H}$ $= 5\frac{1}{2}$ feet.

Testing the stability of the arch rin we get

$$\frac{K}{\frac{2}{3}\text{ of }48} = \frac{H}{H_1} \quad \therefore\ K = 23.3''$$

This number, 23.3, if multiplied by 3 will give 70 inches as the maximum depth of rib at springing. The line of pressure thus falls well within the middle third of the arch-ring at the springing. If 48 inches is considered to be the least thickness of ring at the springing we should find the smallest safe ⅔ of the keystone depth thus $\frac{16}{K} = \frac{H}{H_1}$ $\therefore$ K=22, and 22 is ⅔ of 33. The keystone depth would be thus not less than 2ft. 9in.

The arch under notice is exceptional as regards the amount of surcharged weight, and the thrust along the arch at the springing is thus not so much in excess of the thrust at the crown, as in the previous example. The first example is by no means uncommon in respect to the thickness of roadbed above the arch-ring. We have already noted that such an arrangement is not correct, theoretically, unless the spandril also is filled solid to the road level; but as the roadbed would be solid only for a short distance, the result would not be serious, though it points to the desirability of

making the curvature somewhat sharper at the crown and flatter at the haunches than the theoretical linear arch.

As an arch with immovable abutments cannot crush inwards at any point without absolute crushing of the material, or bulging outwards of some other part, it would also appear better on this score that the curvature of the crown should be flatter than an absolutely correct arch than that the haunch curvature should be so, because, owing to the greater depth and immobility of the load over the haunches than over the crown, any excess of external load, such as the passage of a heavy locomotive, would, if the curvature of the crown was too sharp, tend, when the load was over the haunches, to cause the crown to rise; and though, again, when the load was over the crown, it would also tend to force this in, it would not so readily do this, because of the difficulty of forcing up the haunches on account of the weight of surcharge, and the variation of the true circle from the catenary at the haunches being in the wrong direction, on the basis of the above hypothesis may be taken as indicative of the necessity of greater consideration being bestowed upon the catenary as a figure for arches.

There is no doubt but that friction plays a most important part as a preserver of arches, especially when subject to heavy passing loads; and vibration is to be avoided as destroying friction. A heavy surcharge of earth in preference to or combined with spandril walling would, both as a deadener of vibration and as a means of increasing the ratio of dead to live load, tend to secure stability in an arch.

Between the limits of the two examples we have worked out, possibly fall the majority of stone arches, so far as are concerned depth of loading at crown.

In the Example II. it must be understood that the catenarian curve has been straightway adapted as the actual intrados, the limit of the deviation of the linear arch not exceeding $q=\frac{1}{6}$, while in example I., q being above $\frac{1}{6}$ on the basis of $\frac{t}{t_1}=\frac{H}{H_1}$ the arch-ring, to fulfill this double condition, would require to have been constructed to lie partially on either side of the catenarian curve, the intrados at the springing passing within the catenary, an amount N in this case =6ft. 4in. −5ft. 2in.=14in., as shown by the short dotted line.*

The largest span of any stone bridge is that of the Washington Aqueduct, a single arch of 220 feet, the next being Harrison's famous bridge over the Dee, at Chester, England, 200 feet. Both these are truly circular, and the Washington arch at the springing is, with its solid backing, as much as 20 feet in thickness. In this way practical men have eliminated the effect of deviations in the line of pressures, for however designed and loaded, it is probable that with the careful bonding of the backing courses, a linear arch can be drawn within what may fairly be called the arch-ring; and looking upon it in this light it appears that, so long as the linear arch falls beyond the intrados, and never within it, *i. e.*, within the archway itself and not through the material of the arch-ring, the arch should be practically safe. The catenarian arch being theoretically designed to be an exact linear rib, it appears almost superfluous to take into consideration the possibility of rupture due to deviation of the line of pressure beyond the middle third of the arch-ring; for, by the very theory of the design, the line of pressure of the whole weight of both the arch-ring and the loading coincides at the intrados with the intrados itself, and at the exterior surface of the solid backing with that exterior surface, if the backing has been correctly proportioned, and it would appear superorogatory to investigate the question of stability on this point, though Rankine, referring to this, says the "resulting curve is simply the curve of the intrados shifted vertically upwards through a height AB," thus apparently hinting that the process is necessary, even to a theoretically proportioned structure.

It may be questioned with some force if the catenary curve can compare, in point of appearance, with the circle as a figure for arches. If appearance is to be considered, however, it is an easy matter

* Thus, the actual arch at the springing if designed to fulfill both the condition for K and to be also of equal strength throughout, would have a springing thickness of 6 ft. 4″ to fulfill the latter condition, but in place of having for intrados the true curve T−T and for extrados the curve commencing C−C it would lie between the two curves shown for a short distance only, and shaded, and of a thickness M=6 ft. 4″ in. or [(5 ft. 2)+N)].

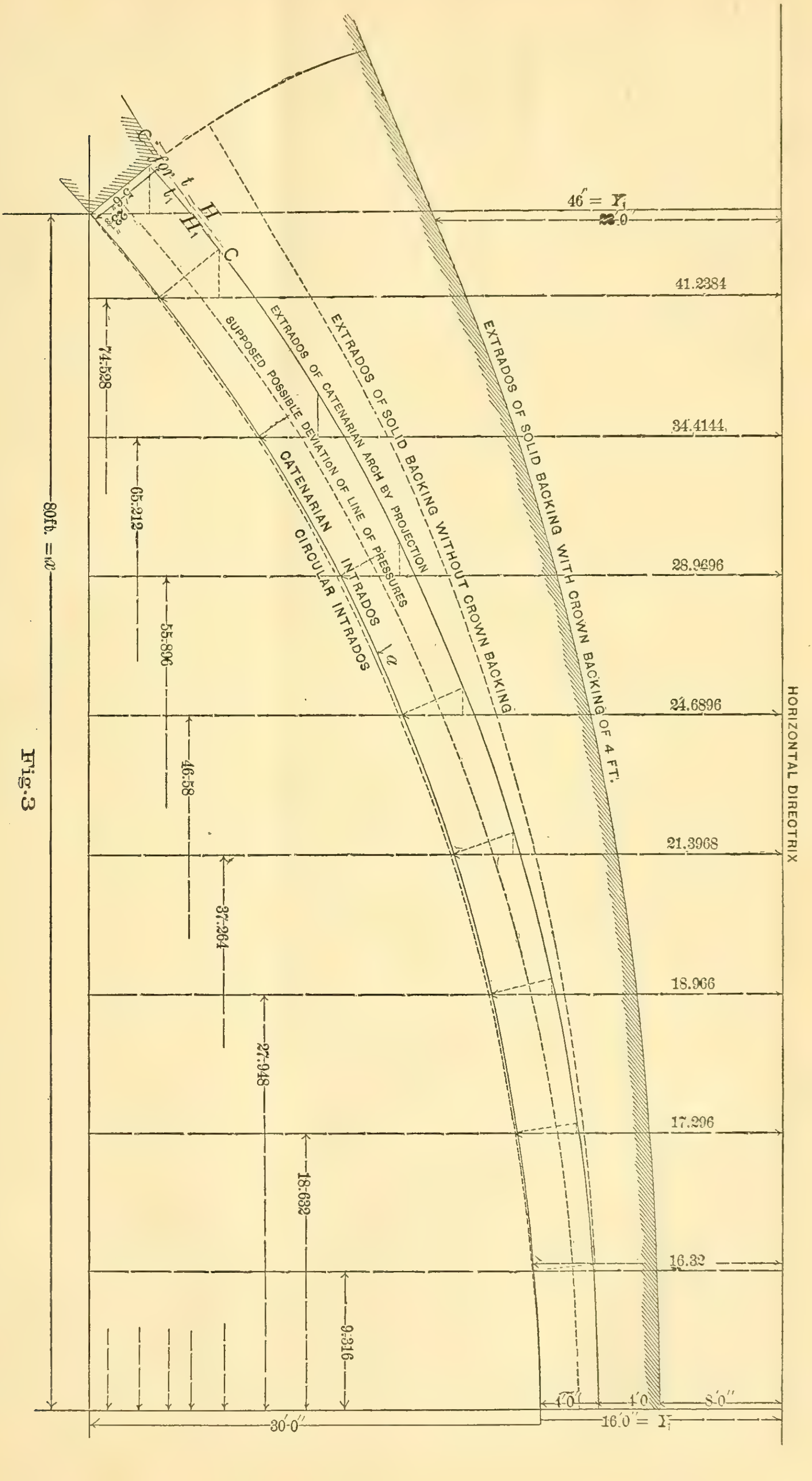

EXTRADOS OF SOLID BACKING WITHOUT CROWN BACKING
EXTRADOS OF SOLID BACKING WITH CROWN BACKING OF 4 FT.
EXTRADOS OF CATENARIAN ARCH BY PROJECTION
SUPPOSED POSSIBLE DEVIATION OF LINE OF PRESSURES
CATENARIAN INTRADOS
CIRCULAR INTRADOS
HORIZONTAL DIRECTRIX
46′ = Y
41.2384
34.4144
28.9696
24.6896
21.3968
18.966
17.296
16.32
74.528
65.212
55.896
46.58
37.264
27.948
18.632
9.316
80ft. = a
30′0″
16′0″ = Y
8′0″
C
H

Fig. 3

to first design the true arch and then so proportion the thickness of the arch-ring that true arch may be contained within an intrados of circular form. It is evident, from Fig. 2, that it is the great weight over the haunches that renders possible the use of the flat crown of the catenarian arch, and opponents of the form may urge that, by properly lightening the haunches of load, the circle may be as mathematically correct as the catenary.

For arches of large spans, however, the catenary curve, presenting, as it does, a direct means of constructing an arch which shall fulfill the conditions of stability if loaded in a manner at which it is easy to arrive, and which presents no difficulties of execution, appears to solve much of the difficulty of the arch question: and it is certain that the headway of a catenarian arch, being greater than that of a circular arch at a little above the springing, tells somewhat in its favor.

The circle may be more eye-pleasing in the opinion of many, but the writer believes that the truer form of the catenary is not displeasing to engineers generally.

In iron structures a notable example of conformity to correct forms is to be seen at Manchester, England, the single-span roof over the Central Station being constructed of a series of latticed ribs of catenarian form of large span. These ribs spring, in reality, from the ground line, though this is to a certain extent concealed by the sidewalls of the station, put in chiefly for effect, and the ribs for some height above the springing are stiffened by being solid plated. This structure is a distinct concession to the requirements of ideal form in engineering construction, and worthy of special notice by engineers.

It is noticeable, however, in the arch of Fig. 3 the circle coincides so nearly with the catenarian intrados as to be practically identical with it; but this is not often the case, the depth of crown load being here exceptional. In this respect the catenary bears resemblance to its fellow curve, the hydrostatic, in requiring the designer's attention chiefly when the arch crown approached the directrix, and as at great depths the intrados of a tunnel approximates to the circular form (modified only by the angle of repose of the earth), so does the catenarian arch also approach the true circle. Hence it is easy to see that the stability which practice has shown to be the feature of a deeply-surcharged arch, may not be due altogether to the frictional stability caused by the load, but partially to the coincidence of the actual intrados with the ideal rib.

In conclusion, the writer would add that if what he has written serves in any way to draw attention to the neglect by engineers of true forms, wherewith at least to analyze the conditions of their actual constructions, he will feel that he has not written in vain.

HEAT ACTION OF EXPLOSIVES.*

From "Iron."

The sixth of the course of lectures on "Heat in its Mechanical Applications" was delivered at the Institution, by Captain Andrew Noble, C. B., F. R. S., M. I. C. E. The lecturer commenced by pointing out that the salient peculiarities of some of the best-known explosives might roughly be defined to be the instantaneous—or, at least, the extremely rapid—conversion of a solid or fluid into a gaseous mass, occupying a volume many times greater than that of the original body, the phenomenon being generally accompanied by a considerable development of measurable heat, which heat played a most important part, not only in the pressure attained, if the reaction took place in a confined space, but in the energy which the explosive was capable of generating. Fulminates of silver and mercury, picrate of potassa, gun-cotton, nitroglycerine and gunpowder, were cited as explosives of this class. The lecturer asserted that substances such as those just named were not the only true explosives. In these solid and liquid explosives, which consisted generally of a substance capable of being burnt, and a

* Abstract of a lecture before the Institution of Civil Engineers.

substance capable of supporting combustion, in, for example, gun-cotton or gunpowder, the carbon was associated with the oxygen in an extremely condensed form. But the oxidizable and oxidizing substances might themselves, prior to the reaction, be in the gaseous form ; as, for instance, in the case of mixtures of air or oxygen with carbonic oxide, of marsh gas with oxygen, or of hydrogen and oxygen. He added that these bodies did not complete the list, and that, under certain circumstances, many substances ordinarily considered harmless must be included under the head of explosives, making a reference to finely divided substances capable of oxidization, or certain vapors which when suspended in, or diluted with, atmospheric air, formed mixtures which had been the cause of many serious explosives.

These instances served to show that an explosive might be either solid, liquid, or gaseous, or any combination of these three states of matter. In the first place, a brief account was given of the substances of which some explosives were composed, illustrated by the composition of one or two well-known types. In the second place, the lecturer showed the changes which occurred when explosives were fired, and gave the substances formed, the heat developed, the temperature at which the reaction took place, and the pressure realized, if the products were absolutely confined in a strong enough vessel ; relating the experiments which had been made, and the apparatus which had been used, either to ascertain or to verify the facts required by theory, He further supposed all the explosives to be placed in the bore of a gun, and traced their behavior in the bore, their action on the projectile, and on the gun itself. He also described the means and apparatus that had been employed to ascertain the pressure acting on the projectile and on the walls of the gun, and to follow the motion of the projectile in its passage through the bore. He mentioned that the potential energy stored up in a mixture of hydrogen and oxygen forming water was, if taken with reference to its weight, higher than that of any other known mixture, and explained why such an explosive, whose components were so readily obtainable, was not employed as a propelling or disruptive agent, the main objection being that if a kilogramme of gunpowder, forming a portion of a charge for a gun, was assumed to occupy a liter or a decimeter cubed, a kilogramme of hydrogen, with the oxygen necessary for its combustion, would at zero and at atmospheric pressure occupy a volume sixteen thousand times as great.

The lecturer next passed to gun-cotton, described its composition and the various forms in which it was manufactured, referring especially to the forms which were so largely due to Sir Frederick Abel. The various forms of gun-cotton were exploded, and the lecturer remarked on the small quantity of smoke formed, as an indication of the small amount of solid matter in the production of combustion. Also, that instead of the explosions which took place when gaseous mixtures were fired, gun-cotton appeared rather to burn violently than explode. This was due to the ease with which the nascent products escaped into the atmosphere, so that no very high pressure was set up ; but it was pointed out that by a small charge of fulminate of mercury, or other means, a high initial pressure was produced, and the harmless ignition shown would be converted into an explosion of the most violent and destructive character. This transformation differed materially from those which he had hitherto considered. In both of these the elements were, prior to ignition, in the gaseous state, and the energy liberated by the explosion was expressed directly in the form of heat. In the present instance a very large but unknown quantity of heat disappeared in performing the work of bringing the products of explosion to the gaseous state.

Captain Noble then showed that gunpowder, the last and most important example selected, was also by far the most difficult to experiment with, as well as the most complicated and varied in the decomposition which it underwent. One great advantage for the artillerist which gunpowder possessed, in being a mixture, not a definite chemical combination, was that when fired it did not explode in the strict sense of the word. It could not, for example, be detonated as could gun-cotton, or nitro-glycerine, but it deflagated with great rapidity, that rapidity varying with the pressure under

which the explosion was taking place. As a striking illustration of the effect of pressure in increasing or retarding combustion, he showed an experiment devised by Sir Frederick Abel. It consisted in endeavoring to burn powder *in vacuo*, and he demonstrated that it would not burn until sufficient pressure was reached. He exhibited the various forms under which gunpowder was manufactured, and ignited some samples of powder, pointing out the essential difference between their combustion and that of gun-cotton, namely the large quantity of what was commonly called smoke slowly diffusing itself in the air. He also exhibited a portion of the so-called smoke of a charge of 15 lb. of powder, collected in a closed vessel.

Captain Noble next described at some length the experiments made with gun-cotton and gunpowder by Sir. Frederick Abel and himself. With reference to the latter he reiterated their opinion that, except for instructional purposes, but little accurate value could be attached to any attempt to give a general chemical expression to the metamorphosis of a gunpowder of normal composition. He further pointed out that heat played the whole rôle in the phenomena. He explained that a portion of this heat, to use the old nomenclature, was latent; it could not be measured by a calorimeter; that was, it had disappeared or been consumed in performing the work of placing a portion of the solid gunpowder in the gaseous condition. A large portion remained in the form of heat, and performed an important part in the action of the gunpowder on a projectile. After describing the apparatus used by Sir Frederick Abel and himself, Captain Noble illustrated the progress that had been made in artillery by mentioning that thirty years ago the largest charge used in any gun was 16 lb. of powder. The 32-pounder gun, which was the principal gun with which the navy was armed, fired only 10 lb.; but he had fired and absolutely retained in one of these vessels, no less a charge than 23 lb. of powder and 5 lb. of gun-cotton.

The lecturer next referred to erosion and its effects, and added that he was not one of those who advocated or recommended the use of gunpowder giving very high initial tensions. If such a course were followed, much would be lost and little gained. The bores of guns would be destroyed in a very few rounds. There was no difficulty in making guns to stand pressures much higher than those to which they were normally subjected, but then they must be in a serviceable condition. Nine-tenths of the failures of guns with which he was acquainted had arisen, not from inherent weakness of the guns when in a perfect state, but from their having, from one cause or another, been placed in a condition in which they were deprived of a large portion of their initial strength. He added that, with a given weight of gun, a higher effect could be obtained if the maximum pressure was kept within moderate limits. He stated that the actual pressure reached by the explosion of gun-cotton experimented with by Sir Frederick Abel and himself, assuming the gravimetric density of the charge to be unity, would be between 18,000 and 19,000 atmospheres, or say 120 tons on the square inch. While at the same density, in a closed vessel with ordinary powder, the pressure reached about 6,500 atmospheres, or about 43 tons on the square inch, he had found it possible to measure the pressure due to the explosion of charges at considerably higher density, and had observed pressures of nearly 60 tons with a density of about 1.2.

The lecturer then considered the case of a charge of gunpowder placed in the chamber of a gun; he supposed the gravimetric density of the charge to be unity, that it was fired, and that it was completely exploded before the shot was allowed to move. He exhibited on a diagram a curve indicating the relation between the tension and the density of the products of combustion when employed in the production of work; and observed that in this diagram the tension was represented by the ordinates, the expansions by the abscissas, and the energy developed by any given expansion was denoted by the area between the corresponding ordinates, the curve, and the axis of abscisses. He said that if this theoretic curve was compared with the curve deduced from experiments in the bores of guns, after the charge might be supposed to be completely consumed, the agreement was most remarkable, and af-

forded ample evidence of the approximate correctness of the theory. He had stated that he could not agree with those who were in favor of the strongest—meaning by the term the most explosive—powder manufactured. To show the advance that had been made by moving in exactly the opposite direction, he exhibited diagrams of two guns of precisely the same weight, but differing in date by an interval of ten years. One of these guns was designed to fire the old-fashioned R. L. G., the other, modern powders. The maximum pressure in the older gun was nearly double that in the modern gun, while the velocity developed by the latter was twice, and the energy not far from three times, that of the former; and if the foot-tons per inch shots' circumference were taken to represent approximately the respective penetrating powers of the projectiles, the superiority of the modern gun would be still more apparent. He directed attention, however, to one point. The new gun was as a thermo-dynamic machine much less efficient than the old. This arose chiefly from the fact that although the new gun was absolutely much longer than its rival, it was, taken in relation to the charge, much shorter; that was, the gases were discharged at the muzzle at a much higher tension.

It remained to consider the total amount of energy stored up in explosives. In the case of the most important—gunpowder—he stated that the total energy stored up was about 340,000 kilogrammeters per kilogram of powder, or, in English measure, a little under 500 foot-tons per lb. of powder. He said that if the potential energy of 1 lb. of gunpowder was compared with that stored up in 1 lb. of coal, his audience being accustomed to the enormous pressures developed by gunpowder, might be somewhat astonished at the results of the comparison. The potential energy of 1 lb. of gunpowder was as nearly as possible $\frac{1}{10}$ of that of 1 lb. of coal, and $\frac{1}{40}$ of that of 1 lb. of hydrogen. It was not even equal to the energy stored up in the carbon which formed one of its own constitueuts. As an economic source of power, coal had the advantage by at least two thousand to one. He had stated that the total theoretic work of gunpowder was a little under 500 foot-tons per lb. of powder, but it might be desirable to mention what proportion of this theoretic work was realized in modern artillery. He concluded by arguing that, were it necessary to urge the claims of the modern science of thermo-dynamics, he might take, as perhaps the most striking instance, the progress of artillery during the last quarter of a century. Twenty-five years ago our most powerful piece of artillery was a 68-pounder, throwing its projectile with a velocity of 1,600 feet per second. Since then the weight of our guns had been increased from 5 tons to 100 tons, the projectile from 68 lb. to 2,000 lb., the velocities from 1,600 feet to 2,000 feet per second, the energies from 1,100 foot-tons, to over 52,000 foot-tons. Large as these figures were, and astonishing as were the energies which in a small fraction of a second could be impressed on a projectile of nearly a ton weight, they sank into the most absolute insignificance when our projectiles were compared with other projectiles, velocities, and energies existing in nature. Helmholtz had given an estimate of the heat that would be developed if the earth were suddenly brought to rest, but if, looking at the earth in an artillery point of view, and following the principles he had laid down, the earth was considered as an enormous projectile, and if it was supposed further the whole energy stored up in gunpowder could be utilized, there would yet be required a charge 150 times greater than its own weight, or 900 times greater than its volume, to communicate to the earth her orbital motion.

A German mile—about five English miles—contains 25,856 ft.; a square German mile contains therefore 668½ million square feet. The superficial area of the Lake of Constance being 8½ German square miles, therefore contains 5682 million square feet. There are living on the surface of the globe at this moment, in round numbers, about 1,430 million human beings. Let every man have 4 square feet allotted to him, and if it were frozen over, the whole human family might find standing room upon the surface of the lake. Should the weight prove too great, the ice break, and the whole human race be submerged, it would only raise the level of the lake about 6 in.

TEMPERATURE OF THE SUN.

BY PROF. DEVOLSON WOOD.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

IN the last March number of this journal is an article by Capt. J. Ericsson, taken from *Nature*, in which occur the following statements, page 180: "Had Pouillet known that solar radiation, after suffering a *two thousand five hundred and seven-fold* diffusion, retains a radiant energy of 520° F., he would not have asserted that the temperature of the solar surface is 1760° C. Accepting Newton's law that the temperature is as the density of the rays, the temperature imparted to the heater of the sun motor proves that the temperature of the solar surface cannot be less than 520°×2507=1,303,640° Fahr. . . . No demonstration whatever has yet been produced tending to *prove* that the said law is unsound. . . . The temperature produced by radiant heat emanating from incandescent spherical bodies diminishes as the diffusion of the heat rays."

The law that "the intensity of heat diminishes as the square of the distance from the radiant increases," here referred to as Newton's law, is applicable only to the case where the radiant body is considered as a mere point; and even in those cases the law does not give the temperature of the incandescent body. The law is sufficiently accurate for finite distances from the radiant *point*, but *at* the point it gives an infinite temperature in all cases; whereas the radiant, in practice, has only a moderate temperature. To be applicable to the sun it must be considered as a point, instead of a heated surface 400,000 miles from its center. Even if the sun be considered as a uniformly heated mass, the law will not be applicable to it; hence the computation given by Capt. Ericsson gives an erroneous value for the temperature. We know of no way of finding the temperature founded on that method. The heat received by his sun motor emanated from all the points of the solar surface seen from the earth, which will be somewhat less than the surface of a hemisphere of the sun.

Experiment shows that the quantity of heat emanated from an incandescent body increases more rapidly than the temperature, and that the law deduced by M. M. Pettit and Dulong is given by the equation

$$Q=1.146\ fa^t$$

Where t is the temperature in degrees centigrade of the hot body, Q=1.0077, f the emissive power of the surface, its superior limit being unity, and r the quantity of heat per square centimeter emitted per minute, being the number of grammes of water raised 1° C. in one minute. Newton's law cannot be substituted for this. Assuming $f=\frac{1}{10}$, Pouillet found the probable temperature of the sun's surface to be 1760° C. A recent determination of the solar constant, by Professor Langley, would, by the same process of analysis, give over 5000° Fahr.

One Rosetti makes the following remark: "The effective temperature of the sun may be defined as that temperature which an incandescent body of the same size placed at the same distance ought to have in order to produce the same thermal effect if it had the maximum emissive power. If we consider the surrounding temperature during the observation to have been 240°, we obtain . . . for the effective temperature 9965.4° C. . . . I think then I may fairly conclude that the temperature of the sun is not very different from its effective temperature, and that it is not less than 10000° C., nor much more than 20000° C." (*Phil. Mag.*, 1879, Vol. II., p. 548; or *American Journal Science and Arts*, 1870, II., 68.)

In regard to this result, it appears that the surrounding temperature was assumed too high. Assuming that the temperature measured in the sun's rays is 125° F., and that the atmosphere absorbs $\frac{1}{5}$ the heat, we would have about 156° F. for the intensity of the heat if none were absorbed by the atmosphere,

and this is nearly 70° C., instead of 240°; and taking $\frac{7}{24}$ of the above results gives from 3000° C to 6000° C, nearly; the smaller of which does not differ largely from the corrected value of Pouillet.

One can scarcely conceive of the intense thermal effect produced by a temperature of 5000° F. It is equivalent to melting 16½ miles thick of ice per day on the sun's surface; and each square foot of the surface would require the hourly consumption of more than 1800 pounds of coal to maintain this heat.

The expression, in the above extract, "radiant energy of 520° F.," is unintelligible, since energy is not so measured. The implication that Pouillet did not take into account the diffusion of the rays, is unjust, for that scientist leaves no doubt on that point, as may be seen in his paper on pages 32 and 33 of *Comptes Rendus* for 1838.

We see no reason for seriously questioning the method of Pouillet. The absorption of the atmosphere varies with the different wave lengths of light, and as measured by Professor Langley ranges from 0.20 to 0.61. Taking the mean as the average absorptive power of the atmosphere, we conclude, according to the method of Pouillet, that the temperature of the solar surface is less than 6000° Fahr.

NOTE ON OPTICAL THEORY OF THE STADIA.

I. O. BAKER, Professor of Civil Engineering, University of Illinois.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

IN the April number, current year, of this Magazine there appeared an article on the stadia, in which exceptions are taken to the ordinary deduction of the formula for the stadia, but which only confounds wisdom with words, and no understanding. The author of that article was misled by the statement of the text-books, which usually precedes the formula for convex lenses, that "neglecting the thickness of the lens, the formula becomes

$$\frac{1}{p}+\frac{1}{p_1}=\frac{1}{f}."$$

It is well known that several approximations are involved in the production of the common formula for convex lens; but if any one will take the trouble to follow the effect of these approximations through to the final result, he will find that they nearly neutralize each other. See, for example, Silliman's Physics, pages 321 and 323.

Although the author of that article discovered that his second formula, as above, was not exact, he failed to notice that his first also involved an approximation. He first assumes that the incident and emergent rays intersect in the optical center; this neglects the lateral displacement of the ray due to its passage through the lens. If the approximations involved in this assumption be also followed through, it will be found that they tend to neutralize the error of the second equation.

The analytical investigation of the effect of the approximations involved in the two fundamental equations, used for the stadia, is too long to be reproduced here, even if it were necessary, besides the writer had no time to attempt it; but having so investigated it, a few years ago, he is prepared to assert that the resulting error in the final formula used for the stadia is wholly inappreciable.

Finally the author of the article in question, seems to think that the errors depend upon the number and form of the component lenses in the objective. The formula for a convex lens is true for any converging lens or combination of lenses, and the more closely the optical center approaches one face, the more accurate the formula, provided this face is placed toward the cross-hairs, as it should be under any circumstances.

If we wish to compute the coefficient $\frac{f}{i}$ in the stadia formula for the horizontal

distance $D = \frac{f}{i}s + (f+c)$, it is not sufficiently exact to determine f by measuring directly from the lens to the focus for parallel rays; it should be determined by measuring the distance between the object and its image when the two are equal in size and equally distant from the lens, one-fourth of this distance is equal to f, no matter what the form of the lens. If f be determined as above, and i carefully measured, the formula will give results correct to the limits of the accuracy of the observations themselves. The writer made a very satisfactory test of this principle by measuring under a microscope the distance between the threads of an astronomical transit, and computing the equatorial intervals from the value of f determined as above; the actual intervals as determined astronomically, agreed within the limits of the error of the observations.

The writer would not be understood as advocating that $\frac{f}{i}$ should be determined in this way, but as showing that no appreciable error is involved in the formula $D = \frac{f}{i}s + (f+c)$. Of course, it is better to measure the larger quantities, D and s, and compute the coefficient $\frac{f}{i}$ therefrom. Almost any measurement of f and c is accurate enough for the term $(f+c)$; but if we choose, we may consider both $\frac{f}{i}$ and $(f+c)$ as unknown, when two measures of D and s will give two equations from which $\frac{f}{i}$ and $(f+c)$ may be determined. For greater accuracy, determine several values of each and take the mean.

[Since writing this article, the June number of this Magazine has been received, which contains a surprisingly brief and elegant analytical discussion fully confirming the above.]

DISCHARGE OF STREAMS IN RELATION TO RAINFALL.

By TIMOTHY AUGUSTINE COGHLAN, Assoc. M. Inst. C. E.

From Selected Papers of the Institute of Civil Engineers.

The country watered by the Upper Nepean, Cordeaux and Cataract rivers, comprises an area of 354 square miles, the mean length from north to south being about 25 miles, while the width from east to west is on the average 16 miles. It is for the most part uninhabitable, and has been reserved by the Government of New South Wales as the source from which the city of Sydney, with its suburbs, is in future to derive its supply of water. The area included within the catchment of these rivers lies on the western side of the range of mountains constituting the watershed between the Nepean Valley and the Illawarra district, and is in no place distant more than 20 miles from the Pacific Ocean. The ridge forming its eastern boundary is known as the Illawarra or Mittagong range, and has an average height of about 2,000 feet above sea-level, the most noteworthy peaks being Mounts Keera and Kembla, opposite the town of Wollongong. The average elevation of the basin is probably not less than 1,200 feet above the sea. On the eastern side of the basin, to the lee of the mountains, the country is flat; numerous swamps retain the water, and serve to some slight extent as a storage reservoir, by equalizing the flow and gradually feeding the tributary streams at the head of the rivers. The swamps occur chiefly in the Cataract part of the watershed, and though considerable in themselves, do not occupy a very large portion of the area. The remainder is a rugged plateau intersected by steep and broken ridges, which sometimes rise perpendicularly from the beds of the streams. The whole country is barren; the surface-soil is poor, resting

in many places almost directly on sandstone, which crops out on the sides and tops of the spurs of the hills and in the beds of the streams. Vegetation is represented by stunted varieties of eucalyptus and epacris, though the scrub is in many places thick; in the valleys and other choice spots the common gum-trees attain goodly proportions.

The main branch of the Nepean rises at the extreme south of the watershed at a point nearly 2,400 feet above the level of the sea, whilst the sources of the Cordeaux and Cataract have an elevation of about 1,400 feet. The rivers, though they rise far apart, converge till the Cordeaux unites with the Nepean at the Pheasant's Nest Pass, after a course of about 24 miles, the length of the Nepean being about 30 miles. Below the junction of these rivers a weir was erected to gauge their united waters. The Cataract approaches the Nepean nearly at right angles, and at Broughton's Pass, 20 miles from its source, at the site of a weir, it is only $4\frac{3}{4}$ miles distant from that river. Here a tunnel is being pierced to divert part of the Nepean and Cordeaux waters to the Cataract, to be thence conducted to Sydney.

Both the Pheasant's-Nest and Broughton's Pass are gorges in the sandstone hills, their sides rising sheer. The fall along the bed of the Nepean is about 70 feet, and of the Cataract nearly 60 feet per mile. The rivers near their sources descend from the hills in miniature cascades. The lay of the basin of these rivers is north and east. To this must be attributed the equable fall of rain over the basin. The records of a long series of years establish the fact that the rain is more copious near the coast than inland, and that the average depth of rain at a particular place generally depends on its distance from the sea.

At Sydney the heavy rainfalls, brought by the south-east winds, are attributable to the peculiar situation of the adjacent district forming part of a region of precipitation, of which the Nepean and Cataract basin is the extreme south, Long since, the Government Astronomer of New South Wales pointed out that on the border of the south-east trade, as on that of the north-east, there is a belt of calms, or changeable winds, and that the polar side of this belt is the region of precipitation. Port Macquarie, in lat. 32° 47′, is usually the limit of the south-east trade wind on the New South Wales coast. Then southward for a few degrees the rainfall is excessive. The configuration of the Nepean and Cataract basin is, moreover, such as to promote the discharge of the rain brought by the trade-winds; while, on the other hand, the clouds gathered by the southerly winds discharge their moisture on the western or lee side of the coast ridge, which has just sufficient elevation to obstruct the passage of the clouds and facilitate precipitation.

Rain gauges have been established at various points in the river basins. The values in Table I. are not for one place, but the adjusted means for the whole district, giving due weight to the area represented by each gauge. The annual fall of rain varies from 75 inches to 34 inches. The average fall since 1869 has been about 54 inches at the Cataract river, while at the Nepean it has been only $44\frac{1}{8}$ inches, or about 82 per cent. of the former. This average holds good both for a series of months and years, the excess on the Cataract basin being attributable to its closer proximity to the sea, the dividing ridge being there only 3 miles distant from the Pacific Ocean, and also to its trending towards the direction from which the heaviest downpour comes. Table I. shows the proportion of water falling on the two basins.

The area of the Nepean basin is about 284 square miles, and of the Cataract about 70 square miles, the proportion being as 4.06 to 1. The average rainfall is 0.825 to one; thus the proportion of rainfall over the Nepean area to that of the Cataract is as 3.35 to 1.

The heaviest rain observed during any month was in February, 1873, when 22.43 inches fell on the Cataract, and 19.78 inches on the Nepean basin; the least was in April, 1871, when 0.24 inch, and 0.10 inch of rain fell at these places. Most of the rain falls from February to July, though heavy rains sometimes occur in September and October. Excessive falls are often due to great rain-storms in the latitudes just beyond the south-east trades. On the 26th of February, 1873, 11 inches of rain were recorded in 24 hours; but cases have been known at Sydney where a depth of 20 inches has

fallen in 24 hours. The average number of rainy days for the year is one hundred and forty; the number of days of continuous rain has been twenty-six, and periods of seven days continuous rain are not unfrequent. Droughts are, unfortunately, also of long duration; thus, from July, 1875, to April, 1876, a period of two hundred and eighty-seven days, the total depth of water falling on the Nepean basin was only 14.93 inches, and from February to October, 1872, being two hundred and thirty-five days, only 10.43 inches fell. The longest time without rain was about twenty days.

The annual evaporation varies from 70 to 30 inches, the mean being 48 inches. These figures are somewhat in excess, as the circumstances under which measurements to ascertain evaporation are made bear little analogy to that of water from lakes, swamps or streams. Bearing this in mind, the annual evaporation from water exposed to the direct effect of the sun may be taken as about 36 inches. But in a country covered with thick scrub, as here, evaporation from the ground is not so considerable as is sometimes supposed. Rain is effective, not so much in direct proportion to the volume falling as according to the distribution of that volume. For instance, at the Cataract river 75 inches in 1873 producd less discharge than 64 inches in 1870; again, 54 inches, which fell in each of the years 1871 and 1874, gave rise to almost the same discharge, while a similar depth of rain in 1875 produced much less flow. In regard to the exceptional discharge of 1870, in the months during which the greater part of the rain fell, it rained nearly every day; the ground was saturated, and the water ran off in streams before evaporation and soakage could take place. During 1874 the discharge was high; the previous year had been wet, particularly in the latter months, and in the first six months of 1874 a considerable depth of rain also fell, the latter half year being dry. In 1875, though the first period of the year was wet, the previous months of 1874 had been dry, and the rain was for that reason not effective.

With regard to the ultimate destination of the rain, assuming 44 per cent. to pass off by streams, as will hereafter appear, the depth of water annually evaporated is 36 inches out of a rainfall of 54 inches, or 66 per cent. This would be, of course, impossible, in view of the volume yielded to the streams; but there are many causes operating to diminish evaporation, by preventing the direct action of the sun, so that in all likelihood the water re-evaporated does not amount, on the average, to much more than 33 per cent. of the rain, the remainder, after deducting the stream discharges, escaping underground. No rule can be laid down in regard to this matter, as the possible evaporation is always greatest when the rain is least, the maximum rainfall being accompanied by the minimum of evaporation. The observations seem to indicate that in years of abundant rain, not more than 15 per cent. of the rain is re-evaporated, the remainder going to feed the streams or being absorbed by the soil. In years of low rainfall the amount of evaporation is from 50 to 60 per cent., while during average years 33 per cent. would represent the rain thus lost. Regarding the disposal of rain underground, part is returned to the rivers by springs through crevices in the rocks, part is absorbed by vegetation, and part is carried away through fissures in the rocks or breaks in the strata to places below the streams. Tunnels and openings in the Sydney sandstone show that waste from this last source is considerable.

Convenient points were chosen for the erection of the weirs, the rivers being dammed by planks of Oregon pine, $2\frac{1}{2}$ inches thick, bolted to the rock in the bed of the river and calked with oakum. The notch at the Cataract was 3 feet 6 inches, and at the Nepean 10 feet wide, both being 1 foot deep. The formula given by Rankine,

$$Q=5.35\, c\, b\, h^{\frac{3}{2}},$$

was used in calculating the discharge when the water falling over the wier was less than 1 foot deep, c being considered as 0.598; thus the formula reads

$$Q=b\, h^{\frac{3}{2}}=\text{cubic feet per second.}$$

When the water rose over the top of the notch to a moderate height, the discharge was taken as that of a drowned weir. Elaborate observations were made to ascertain the discharge of the rivers when in flood; various cross sections were taken, and the velocities measured at the

different flood heights when opportunities offered, and the results for each cross section were compared. The inclinations of the rivers were also recorded at suitable points, the probable discharges calculated therefrom, and the new results compared with the former ones and with one another, and in this way a table of the probable discharge at each foot in height was arrived at. The results hereafter stated may be considered fair approximations of the discharges of the rivers.

Gaugings were commenced towards the close of the year 1868, and they are still carried on. From this period of upwards of fourteen years, during the interval from July, 1869, to June, 1876, which has been selected as containing illustrations of all the circumstances that need remark, the average annual depth of rain was 53.99 inches on the Cataract basin, and 44.28 inches on that of the Nepean, the proportion being as 1 to 0.823; but as the area of the basin of the former river was hardly one quarter of the latter ($\frac{70}{284}$), the proportion of rain falling on each district was as 1 to 3.34. The average yearly discharges were 24,484,000,000, and 80,383,000,000 gallons, equivalent to 24.14 and 19.54 inches of rainfall respectively, or, allowing for the superior area of the Nepean, as 1 to 3.28.

The records of rainfall and disharge for any particular year show that the dry years are somewhat in favor of the smaller area, while the wet years give either corresponding results, or are in favor of the Nepean. It has been usual to assume that the proportions would be in favor of the smaller area, this proportion being reckoned as a to $A\frac{3}{2}$, where $a=$ discharge per unit of the smaller, and A that for the larger area. The observations taken at the Nepean and Cataract rivers, on the contrary, indicate that the total flow of water from similar districts is in proportion to the volume of the rainfall and the area of each district, bearing in mind always that there is no great disparity in the two areas. The proportion between rainfall and discharge is, in the case of the Cataract, 44.7 per cent., while in the Nepean it is 44.1 per cent. for an extended period, including every condition of flood and drought. This is a much larger proportion than is generally reckoned on; but, if there be any error, it is on the side of being short of the full quantity, owing to the rapidity with which freshets rise in districts of heavy rainfall, and the difficulty of measuring their volume. The average of freshets is about 54 per cent. of the rainfall, while, after the ground has become saturated with previous rain, the volume discharged is nearly equal to the quantity of rain falling. In dry seasons the volume of the streams bears but a small proportion to the depth of rain, from 10 to 12 per cent. being the average yield. The tables show various comparisons between the two streams in regard to the rainfall and the flow due to that rainfall, from which it is evident that their discharges, notwithstanding the difference in drainage areas, is in proportion to the rainfall, the dry periods being decidedly in favor of the smaller area; but the quantity of rainfall and water carried off by the streams in droughts is so small that when the whole is comprised the discrepancy is not shown.

Rejecting the incomplete years 1869 and 1876, it will be seen in the Nepean River, when arranged (a) according to the rainfall, (b) the discharge, and (c) the proportion of rain discharged (the years giving the largest results being placed first on the list), that for the Nepean River the years come in the order shown in Table II. The result of the grouping shows that the greatest rainfall is attended by the greatest discharge, and also by the greatest proportion of discharge to rainfall; and not only so, but the years follow in every case in their proper order. Of course this cannot be looked upon as other than a coincidence, remarkable certainly, but still only a coincidence. Turning now to the Cataract, the years in the same way are as shown in Table III. This is satisfactory, except in respect to 1873, which was a year of abundant rain, though the flow was not proportionate to the rain. The deduction to be derived from this and the preceding Table is obvious. The quantity of water carried off by a stream is not directly proportional to the rainfall; but the greater the quantity of rain falling within a given time, the greater is the percentage of that rain carried off by the streams.

In rainy periods the greatest floods,

TABLE I.—SHOWING PROPORTION OF RAINFALL DISCHARGED BY EACH RIVER.

Year.	Rainfall.		Discharges in Inches of Rain.		Per Centage of Rain Discharged.		Proportion of Nepean Rain to Cataract Rain.	Proportion of Nepean Discharge to Cataract Discharge.
	Cataract.	Nepean.	Cataract.	Nepean.	Cataract.	Nepean.		
1869....	14.35	12.77	4.48	1.82	31.22	14.3	89.00	40.8*
1870....	64.16	64.01	43.30	43.66	67.48	68.20	99.70	100.8
1871....	53.70	43.36	26.54	21.23	49.42	49.00	80.8	80.0
1872....	40.23	34.37	10.53	6.85	26.17	19 93	85.4	65 0
1873....	75 08	57.49	32.58	28.40	43.38	49.40	76.98	88.71
1874....	54.38	42 50	27.33	17.30	50.25	40.70	78.15	63.30
1875....	54.36	41.28	20.42	13.79	37.6	33.40	75.9	67.5
1876....	21.30	16.06	4.84	1.44	22.74	9.00	75.4	29.75*
Average	53.99	44.28	24.14	19.54	44.70	44.10	82.00	81.00

* Six months.

TABLE II.—NEPEAN RIVER. / TABLE III.—CATARACT RIVER.

Table II. (a) Rainfall.	Table II. (b) Discharge.	Table II. (c) Proportion of Rainfall to Discharge.	Table III. (a) Rainfall.	Table III. (b) Discharge.	Table III. (c) Proportion of Rainfall to Discharge.
1870	1870	1870	1873	1870	1870
1873	1873	1873	1870	1873	1874
1871	1871	1871	1874*	1874	1871
1874	1874	1874	1875*	1871	1873
1875	1875	1875	1871*	1875	1875
1872	1872	1872	1872	1872	1872

* Nearly equal.

not only actually, but proportionately to area of basin, were experienced first in the Nepean, notwithstanding its area was four times as large as that of the adjacent stream, though during the whole time of flood almost similar proportions of the rain were measured as given off by the two streams. This may be accounted for by the existence of large swamps in the Cataract district, which act as flood moderators, whereas in the Nepean very little of the rain is retained by the swamps; to this fact, likewise, must be attributed better results from the dry-weather discharge of the Cataract.

Experience elsewhere has led to the conclusion that flood volumes are proportionately greater for smaller areas, and formulas have been constructed on this basis; but the experience derived from streams in New South Wales does not favor this assumption, though it may be correct in the main. The great floods of the Nepean rise 60 feet, but remain at that height only a short time; for instance, on the 23d of February, 1873, the Nepean flowed 1.20 foot over the sill of the weir, on the 24th 4.15 feet, on the 25th about the same, but on the 26th a depth of 55 feet of water was measured at eleven o'clock, and of 60 feet later in the day; twenty-four hours afterwards the depth was 30 feet; on the 28th the river ran 10 feet deep, gradually falling to 4 feet five days afterwards. The quantity passing down during the height of the flood in twenty-four hours was probably 30,000,000,000 gallons, which would make the coefficient c in the formula,

$$\Phi - c \times 27\ (M)\ \tfrac{1}{2}$$

equal to 120, instead of 28, as usually adopted.

By Fanning's formula, where

$$\Phi = 200\ (M)\ \tfrac{5}{6},$$

Φ=cubic feet per second, and M=area of watershed in miles, the result is about 12,000,000,000 against 30,000,000,000 gals., as above stated. This was an extraordinary

instance, floods in general being not more than 40 feet over the sill, giving a daily discharge at the top of the flood of about 18,090,000,000 gallons, a quantity much beyond the scope of the formula.

The Nepean River, therefore, hardly comes within the limits contemplated by the authors of these formulas, though in the Cataract there is a nearer approach to the result derived from the formula. In the latter stream the flood rises 24 feet, and discharges a volume in twenty-four hours of 3,787,000,000 gallons, while the formula of Fanning gives 3,768,000,000 gallons.

No attempt is here made to bring flood volumes within the bounds of a rigid mathematical formula, there being no agreement between the two rivers to admit of such, especially as the principle, that the floods of the larger area are proportionately less than those of the smaller, would be violated. But though in isolated floods no agreement is observable, yet in the general results of large and small flows, as compared with the rainfall, there is ample evidence of the operation of fixed laws.

From the 28th of August 1869, when both streams were low, till the first of May, 1876, the end of a long continued drought, a succession of freshets occurred over periods of time varying from three hundred and six to fourteen days, alternating with intervals of small flow, the longest of which was 287 days. The total quantity of rain causing floods or freshets during these periods was, in the Cataract River, about 290.98 inches, of which 153.86 inches, or about 53 per cent., flowed over the sill of the weir. In the Nepean basin 239.87 inches fell, and 124.17 inches, or 52 per cent., of this quantity passed down the stream, the percentage being nearly the same in each case. The largest ratio of flow to rainfall in the Cataract was nearly 70 per cent., the least for any considerable time was 26.6 per cent. In the Nepean the largest proportion was 67.76 per cent., the lowest 23.6 per cent. The total time occupied by freshets was eleven hundred and sixty-two days, and that reckoned as ordinary flow was eleven hundred and one days. The average rainfall for the Cataract during freshets was 0.25 inch per day, the quantity carried off giving an equivalent of 0.133 inch per day. At the Nepean the average rain amounted to 0.207 inch, the greatest discharge being equivalent to a little more than 0.107 inch. The author's measurements show that during freshets the proportion of water carried off by a stream is greater or less according as the time during which the freshets last is longer or shorter, other things being equal. This law is apparent in the whole series from 1868 to the present time.

The formula, used by the author for the calculation of the quantity of water due to freshets from natural drainage districts of moderate size, is an empirical one, but can be relied on fairly well within certain limits; it is

$$P = t\,c\,R^{1 \cdot 9}.$$

Where P = inches of rainfall discharged by streams.

t = coefficient for time, the value of which is governed by the length of time the freshets last.

c = coefficient of rainfall varying with the quantity of rain.

R = average daily rainfall in inches during freshet.

Not less important than the observation of streams in flood is the determination of their ordinary flow; in fact the latter is of greater moment to an engineer seeking for an efficient water supply. For the eleven hundred and one days of ordinary flow, the rainfall was 73.74 inches at the Cateract, and 59.42 at the Nepean river. being an average daily fall of 0.070 and 0.055 inch. The rain yielded a gross equivalent flow of 8.73 and 5.90 inches, or a percentage of 11.8 in the one case, and of 10.0 in the other. Statements of the different low discharges are arranged in the order of occurrence in Tables IV. and V. Both these tables are to some extent inconsistent. The cause lies in the difficulty of determining the exact time when a dry period begins. No matter how low the water may be in the streams, there is always some water due to the wet period preceding the dry one. This cause of error also operates in rainy weather, but not to a serious extent, as the water due to previous rain forms but a small portion of the whole flow, whereas in the case of low discharges

TABLE IV.—CATARACT RIVER.

Length of Low Discharge.	Rainfall.		Discharge.	
	Total.	Per Day.	Equivalent of Rain.	Proportion to total rain.
190 days.	15 44 inches.	0.081 inch.	2.72 inches.	17.6 per cent.
194 "	14.72 "	0.076 "	1.78 "	12.1 "
162 "	6.60 "	0.040 "	0.80 "	12.1 "
34 "	1.60 "	0.048 "	0.17 "	10.6 "
17 "	0.27 "	0.016 "	0.14 "	51.9 "
13 "	0.26 "	0.020 "	0.13 "	36.1 "
54 "	3.28 "	0.060 "	0.67 "	20.4 "
20 "	2.07 "	0 104 "	0.23 "	11.1 "
147 "	8.73 "	0.059 "	1.01 "	11.6 "
287 "	20.67 "	0.090 "	1.08 "	5.2 "

TABLE V.—NEPEAN RIVER.

Length of Low Discharge.	Rainfall.		Discharge.	
	Total.	Per Day.	Equivalent of Rain.	Proportion to total rain.
190 days.	14.74 inches.	0.077 inch.	1.61 inch.	11.1 per cent.
194 "	10.63 "	0.055 "	1.18 "	11.1 "
162 "	5.21 "	0.032 "	0.55 "	10.4 "
34 "	1.93 "	0.057 "	0.19 "	9.8 "
17 "	0.23 "	0.013 "	0.08 "	34.8 "
13 "	0.38 "	0.030 "	0.09 "	23.7 "
54 "	2.38 "	0 052 "	0.38 "	12.3 "
20 "	1 42 "	0.061 "	0.11 "	9.7 "
147 "	7.67 "	0.052 "	0.68 "	8 9 "
287 "	14.93 "	0.052 "	1.04 "	7.0 "

this item may be a factor sometimes to the extent of 50 per cent. The practice followed by the author is to count as available only 10 per cent. of the rainfall for periods of small flow up to one hundred fifty days; for the succeeding fifty days the amount taken is 8 per cent.; for the following fifty days, 6 per cent., and for the next fifty days, 4 per cent. This gives three hundred days in a period of exceptional drought. The above is less than the practice genereally obtaining elsewhere, but it is warranted by the frequently great heat of the dry summers. During the drought in 1875–76, which lasted for more nine months, the discharge at the Nepean river in the first half of the period, after deducting the water due to previous rainfall, was equal to about 9 per cent. of the rain; whilst during the latter part of the discharge was only equal to 4 per cent. The Cataract during the time yielded a still smaller percentage.

The conclusion to be drawn from the gauging in season of small flow is, that for periods of like rainfall the discharge of the streams is greater or less, accord-as the time over which the rainfall extends is or less greater. This general rule is subject to modification from various causes, the chief being the extent of evaporation, and the volume of rainfatl within short periods, sueh exceptions not invalidating the general principles laid down as to relative discharges.

Regarding the economical size of the channel to deliver water from streams to a storage at some distanca, it is difficult to define exact rules, as the useful discharge depends greatly upon the equable distribution of thc rain throughout the year, and on the retention of large quantities of water in swamps, sand-drifts, or

such like natural reservoirs, until delivred to the streams, when they begin to fall off in volume.

Perhaps as good an example of natural storage as could be found is afforded by the Botany and Lachlan swamps, whence the city of Sydney at present draws its supply of water. The swamps and sand-drifts now comprise an area of about 8 square miles, though for years the area supplying Sydney was not more than $5\frac{3}{4}$ miles. From the latter area a supply of water has been drawn equal to about 18 inches of rain, while the total depth of rain on the average is not much more than two-and-a-half times that quantity. From the 1st of January to the 8th of April, 1876, the latter portion of the drought, during which scarcely 12 inches of rain fell in nine months, and only 4.10 inches in the above-named period, the water in the swamps was carefully gauged, and it was ascertained that the amount drawn off for consumption was about 400,000,000 gallons; the volume of water by evaporation in excess of rainfall may be taken at 116,000,000, whilst the quantity available within the dams at the end of the period was 51,000,000 gallons, giving a total of 567,000,000 gallons used or available for use during period. Against this quantity is to be set the water in the various reservoirs upon the 1st of January, 1876, which amounted to 173,000,000 gallons, leaving 394,000,000 gallons unaccounted for. This represents an equivalent of about 7 inches of rain over the whole available Botany portion, comprising an area of 4 square miles. It was drawn entirely from the sand, and as the water-levels on the inner side of the dams were reduced, the water pouring in from the sand increased in volume, so that in April the discharge was 500,000 gallons per day more than at the beginning of the year, whilst the rainfall was so small as to be negligible.

In the Nepean and Cataract rivers an equable flow depends almost entirely upon the distribution of the rain; thus at the Cataract, 75 inches of rain in 1873 were of very little more value for water-supply than 54 inches in the following year. This was owing to the rainfall in 1874 having been better distributhd than in the previous year.

If the average daily volume of a stream be taken as a standard, and a channel be assumed as capable of carrying off the whole of this quantity, provided the stream was of the same dimension each day, the actual discharge of such a channel would be about 41 per cent. of the whole discharge of the stream, the remaining 59 per cent. not being available from the floods bringing down a far greater body of water than the channel could carry off, even though its capacity were equal to the mean discharge. If the capacity of the channel were one half the mean daily discharge, it would convey 26 per cent. of the total discharge. A channel equal to one-fourth of the mean daily flow would carry off nearly 17 per cent. of that quantity; while a channel, with a capacity equal to one-eighth the mean discharge, would convey 10 per cent., and one equal to one-twentieth would yield very nearly 5 per cent., or about as much as its maximum discharge.

The formula used by the author in establishing the economical size of channel is

$$\Phi=\left(\frac{R}{12}\times\frac{D}{4}\right)$$

where $\Phi=$ the equivalent in inches of rain that would be carried down by a channel equal to the mean daily discharge of the stream; $R=$ the rainfall during any year, and $D=$the discharge for such year in inches of rain. For any channel of less capacity than the average daily discharge, the formula becomes

$$\Phi=c\left(\frac{R}{12}+\frac{D}{4}\right),$$

where $\Phi=$quantity conveyed by channels of various sizes, c being the coefficient varying with the size of channel. The value of c for a conduit equal to the daily average of the stream feeding the conduit is 1.00. Table VI.

Table VI.

For conduit equal to		75	per cent.	$c=0.835$
"	"	50	"	$c=0.634$
"	"	25	"	$c=0.380$
"	"	$12\frac{1}{2}$	"	$c=0.253$
"	"	$7\frac{1}{2}$	"	$=0.160$
"	"	5	"	$=0.118$

Where the proportion between R and D is known, bs is frequently the case, the formula becomes

$$\Phi=\frac{c\,(1+3n)\ \mathrm{R}}{12},$$

where n R=discharge D; Φ and R as above; c being the coefficient varying with the size of the conduit.

The interval to which direct reference is made in this paper only extends from 1869 to 1876; but the whole period during which gaugings have been taken has been used for correcting formulas, or for the purpose of comparison, the mean results for the restricted period agreeing with those the whole period from 1869 to the dresent time.

The formulas and conclusions are intended in the first place to illustrate the conditions of flow in small mountain streams in Few South Wales; but the circumstances connected with the Australian climate are not, as is often assumed, very different from those which obtain in other parts of the world, and it is therefore probable that the experience acquired in New South Wales may be of use in similar circumstances elsewhere.

THEORY OF MAGNETISM.*

By PROF. D. E. HUGHES, F. R. S.

From "English Mechanic and World of Science."

The theory of magnetism, which I propose demonstrating this evening, may be termed the mechanical theory of magnetism, and, like the now well-established mechanical theory of heat, replaces the assumed magnetic fluids and elementary electric currents by a simple, symmetrical mechanical motion of the molecules of matter and ether.

That magnetism is of a molecular nature has long been accepted, for it is evident that, no matter how much we divide a magnet, we still have its two poles in each separate portion; consequently we can easily imagine this division carried so far that we should at last arrive at the molecule itself possessing its two distinctive poles; consequently, all theories of magnetism attempt some explanation of the cause of this molecular polarity, and the reason for apparent neutrality in a mass of iron.

The influence of mechanical vibrations and stress upon iron in facilitating or discharging its magnetism, as proved by Matteucci, 1847, in addition to the discovery by Page, 1837, of a molecular movement taking place in iron during its magnetization, producing audible sounds, and the discovery by Dr. Joule, 1842, of the elongation of iron when magnetized, followed by the discoveries of Guillemin, that an iron bar bent by a weight at its extremity would become straight when magnetized; also that magnetism would tend to take off twists or mechanical strains of all kinds—together with the researches of Matteucci, Mariana, De la Rive, Sir W. Grove, Faraday, Weber, Wiedemann, Du Moncel, and a host of experimenters, including numerous published researches by myself—all tend to show that a mechanical action takes place whenever a bar of iron is magnetized, and that the combined researches demonstrate that the movement is that of molecular rotation.

De la Rive was the first to perceive this, and his theory, like those of Weber, Wiedemann, Maxwell, and others, is based upon molecular rotation. Their theories, however, were made upon insufficient data, and have proved to be wrong as to the assumed state of neutrality, and right only where the experimental data clearly demonstrated rotation.

I believe that a true theory of magnetism should admit of complete demonstration, that it should present no anomalies, and that all the known effects should at once be explained by it.

From numerous researches I have gradually formed a theory of magnetism entirely based upon experimental results, and these have led me to the following conclusions:

1. That each molecule of a piece of iron, as well as the atoms of all matter, solid, liquid, gaseous, and the ether itself, is a separate and independent mag-

* A lecture delivered before the Royal Institution, slightly condensed.

net, having its two poles and distribution of magnetic polarity exactly the same as its total evident magnetism when noticed upon a steel bar-magnet.

2. That each molecule, or its polarity, can be rotated in either direction upon its axis by torsion, stress, or by physical forces such as magnetism and electricity.

3. That the inherent polarity or magnetism of each molecule is a constant quantity like gravity; that it can neither be augmented nor destroyed.

4. That when we have external neutrality, or no apparent magnetism, the molecules or their polarities arrange themselves so as to satisfy their mutual attraction by the shortest path, and thus form a complete closed circuit of attraction.

5. That when magnetism becomes evident, the molecules or their polarities have all rotated symmetrically, producing a north pole if rotated in a given direction, or a south pole if rotated in the opposite direction. Also, that in evident magnetism we have still a symmetrical arrangement, but one whose circles of attraction are not completed except through an external armature joining both poles.

6. That we have permanent magnetism when the molecular rigidity—as in tempered steel—retains them in a given direction, and transient magnetism whenever the molecules rotate in comparative freedom—as in soft iron.

EXPERIMENTAL EVIDENCES.

In the above theory the coercive force of Poisson is replaced by molecular rigidity and freedom; and as the effect of mechanical vibration, torsion and stress upon the apparent destruction and facilitation of magnetism is well known, I will, before demonstrating the more serious parts of the theory, make a few experiments to prove that molecular rigidity fulfills all the requirements of an assumed coercive force.

I will now show you that if I magnetize a soft iron rod the slightest mechanical vibration reduces it to zero; whilst in tempered steel or hard iron the molecules are comparatively rigid, and are but slightly affected. The numerous experimental evidences which I shall show prove that whilst the molecules are not completely rigid in steel, they are comparatively rigid when compared with the extraordinary molecular freedom shown in soft iron. (Experiments shown.)

If I now take a bottle of iron filings, I am enabled to show how completely rigid they appear if not shaken; but the slightest motion allows these filings to rotate and short-circuit themselves, thus producing apparent neutrality. Now I will restore the lost magnetism by letting the filings slowly fall on each other under the influence of the earth's magnetic force; and here we have an evident proof of rotation producing the result, as we can ourselves perceive the arrangement of the filings. (Experiment shown.)

If I take this extremely soft bar of iron, you notice that the slightest mechanical tremor allows molecular rotation, and consequent loss or change of polarity; but if I put a slight strain on this bar, so as to fasten each molecule, they cannot turn with the same freedom as before, and they now retain their symmetrical polarity like tempered steel, even when violently hammered. (Experiment shown.)

We can only arrive at one conclusion from this experiment, viz., that the retention of apparent magnetism is simply due to a frictional resistance to rotation; and whenever this frictional resistance is reduced, as when we take off a mechanical strain, or by making the bar red hot, the molecules then rotate with an almost inconceivable freedom from frictional resistance.

CONDUCTION.

You notice that if I place this small magnet at several inches' distance from the needle it turns in accordance with the pole presented. How is the influence transmitted from the magnet to the needle? It is through the atmosphere and the ether, which is the intervening medium. I have made a long series of researches on the subject, involving new experimental methods, the results of which are not yet published. One result, however, I may mention. We know that iron cannot be magnetized beyond a certain maximum, which we call its saturation point. It has a well-defined curve of rise to saturation, agreeing completely with a curve of force produced by the rotation of a bar magnet, the force of

which was observed from a fixed point. I have completely demonstrated by means of my magnetic balance that our atmosphere, as well as Crooke's vacuum, has its saturating point exactly similar in every respect to that of iron: it has the same form through every degree. We cannot reduce or augment the saturating point of ether; it is invariable, and equals the finest iron. We may, however, easily reduce that of iron by introducing frictional resistance to the free motion of its molecules.

From consideration of the ether having its saturating point, I am forced to the conclusion that it could only be explained by a similar rotation of its atoms as demonstrable in iron.

Reflection would teach us that there cannot be two laws of magnetism, such as one of vibrations in the ether and rotations in iron. We cannot have two correct theories of heat, light, or magnetism; the mode of motion in the case of magnetism being rotation, and not vibration.

Let us observe this saturation point of ether compared with iron. I pass a strong current of electricity in this coil. The coil is quite hot, so we are very near its saturation. I now place this coil at a certain distance from the needle (8in.); we have now a deflection of 45° on the needle. I now introduce this iron core, exactly fitting the interior previously filled by the ether and atmosphere. Its force is much greater, so I gradually remove this coil to a distance, where I find the same deflection as before (45°). This happens to be at twice the distance, or 16in., so we know, according to the law of inverse squares, that the iron has four times the magnetic power of the ether. But this is only true for this piece of iron; with extremely fine specimens of iron I have been enabled to increase the force of the coil forty times, whilst with manganese steel containing 10 per cent. of manganese it was only 30 per cent. superior. We see here that the atmosphere is extremely magnetic. Let us replace the solid bar by iron filings. We now only have twice the force of ether. Replace this by a bottle of sulphate of iron in a liquid state: it is now a mere fraction superior to the atmosphere; and if we were still further to separate the iron molecules, as in a gaseous state, it is reasonable to suppose that if we could isolate the iron gas from that of ether, that iron gas would be strongly diamagnetic, or have far less capacity than ether, owing to the great separation of its molecules. These are assumptions, but they are based upon experimental evidences, which give them value.

Let us quit the domain of assumption to enter that of demonstration. Here I have a long bar of neutral iron. If I place this small magnet at one end, we notice that its pole has moved forward 3in., having a consequent point at that place. Let us now vibrate this rod, and you notice the slow but gradual creeping of the conduction until at the end of two seconds it has reached 14in. The molecules have been freed from frictional resistance by the mechanical vibrations, and have at once rotated all along the bar. Let us repeat this experiment by heating the rod to red heat. You notice the gradual creeping or increased conduction as the heat allows greater molecular freedom. Let us now again repeat this experiment by sending a current of electricity through the bar. You notice the instant I touch the bar with this wire, conveying the current through it, that we have identically the same creeping forwards, no matter what direction of the current. If you simply looked at the effects produced, you conld not tell which method I had employed; either mechanical vibrations, heat vibrations, or electrical currents. Consequently, knowing the two first to be modes of motion, it is fair to assume that an electrical current is a mode of motion, the manner of which is at present unknown; but that there is a molecular disturbance in each case is evident from the experiments shown.

NEUTRALITY.

If I take this bar of soft iron, introduce it in the coil, and pass a strong electric current through the coil, you notice that it is intensely magnetic, holding up this large armature of iron and strongly deflecting the observing needle. I now interrupt the current, the armature falls, and the needle only shows traces of the previous intense magnetization. What has become of this polarity, or what has caused this sudden neutrality? Coulomb supposes that the magnetic fluids have

become mixed in each molecule, thus neutralizing each other. Ampere supposes that the elementary currents surrounding each molecule have become heterogeneous. De la Rive, Wiedemann, Weber, Maxwell, and all up to the present time have accounted for this disappearance as a case of mixture of polarities or heterogeneous arrangement.

My researches proved to me that neutrality was a symmetrical arrangement; I stated this in my paper upon the theory of magnetism to the Royal Society last year. I have since made a long series of researches upon this question, which demonstrate beyond question—1. That a bar of iron under the influence of a current or other magnetizing force is more strongly polarized on the outside than in the interior; that its degree of penetration follows the well-defined law of inverse squares up to the saturation point of each successive layer. 2. The instant that the current ceases a reaction takes place, the stronger outside reacting upon the weaker inside, completely reversing it, until its reversed polarity exactly balances the external layers.

We might here suppose that there existed two distinct polarities at the same end of a neutral bar, but this is only partially true, as the rotation of the molecules from the inside to the exterior is a gradual, well-defined curve, perfectly marked. In a large solid bar the reversed polarity would be in the interior; but in a thin bar, under an intense field, the reversed polarity would be on the outside. Thus, a bar which had previously strong north polarity under an external influence would, the instant it formed its neutrality, have a north polarity in the interior covered or rendered neutral by an equal south exterior, the sum of both giving the apparent neutrality that we notice.

If I take this piece of soft steel and magnetize it strongly it has a strong remaining magnetism, or only partial neutrality. If I now heat this steel to redness, or put it into a state of mechanical vibration, the remaining magnetism almost entirely disappears, and we have apparent neutrality. This piece of steel being thin ($\frac{1}{2}$ millimeter), I know that the outside is reversed to its previous state. I place this piece of steel in a glass vase near the observing needle, and at present there seems no polarity. I now pour dilute nitric acid upon it, filling up the vase. The exterior is now being dissolved, and in a few minutes you will see a strong polarity in the steel, as the exterior reversed polarity is dissolved in the acid.

Let us observe this by a different method. I take two strips of hard iron, and magnetize them both in the same direction.

If I place them together and then separate them, there seems no change, although in reality the mere contact produced a commencement of reversal. Let us vibrate them whilst together allowing the molecules greater freedom to act as they feel inclined; and now, on separating, we see that one strip has exactly the opposite polarity to the other, both extremely strong, but the sum of which, when placed together, is zero, or neutrality.

Let us take two extremely soft strips placed together and magnetized whilst together. On withdrawal of the inducing force the rods are quite neutral.

We now separate these strips, and find that one is violently polarized in one direction, whilst the other is equally strong in the reversed, the sum of both being again zero.

We might suppose that the reaction is due to having separate bars. I will now demonstrate that this is not the case by magnetizing this large $\frac{3}{4}$-in. bar with a magnetizing force just sufficient to render the rod completely neutral when held vertically or under the earth's magnetic influence.

You notice that it is absolutely neutral, all parts as well as the ends showing not the slightest trace of polarization. I reverse this bar, and you perceive that it is now intensely polarized. This is due to the fact that the earth's influence uncovers or reverses the outside molecules, and consequently they are now of the same polarity as its interior. Upon reversing this rod the magnetism again disappears, and reappears if turned as previously. We have thus a rod which appears intensely magnetic when one of its ends is lowermost, whilst if that same end is turned upwards, all traces of magnetism disappear.

INERTIA.

I have remarked in my researches that

the molecules have true inertia, that they resist being put in motion, and if put in motion will vanquish an opposing resistance by their simple momentum. To illustrate this I take this large $\frac{3}{4}$-in. bar magnetize it so that its south pole is at its lowest end. We know that the earth's influence is to make the lower end north. I now gently strike it with a wooden mallet, and the rod immediately falls to zero. I continue these blows, but the rod obstinately refuses to pass the neutral line to become north, the reason being in so doing it would have to change the whole internal reversed curve that I have discovered. It requires now extremely violent and repeated blows from the mallet to make it obey the earth's influence.

Let us repeat this experiment by starting the molecule rapidly in the first instance. The rod is now magnetized south, as before. I give one single sharp tap; the molecules run rapidly around, pass through neutrality, breaking up its curve, and arrive at once to strong north polarity.

A very extraordinary effect is shown if we produce this effect by electricity; it then almost appears as if electricity itself had inertia. I take this bar of hard iron and magnetize it to a fixed degree. On the passage of the current you notice that the magnetism seems to be increased as the needle increases its arc, but this is caused by the deflection of the electric current in the bar. The current is now obliged to travel in spirals, as my researches have proved to me that electricity can only travel at right angles to the magnetic polar direction of a molecule, consequently in all permanent magnets the current must pass at right angles to the molecule, and its path will be that of a spiral. Let us replace this bar by one from a similar kind of iron, well annealed. The molecules here are in a great state of freedom. We now magnetize this rod to the same degree as in the previous case; the electric current now, instead of being deflected, completely rotates the molecules, and the needle returns to zero, all traces of external magnetism having ceased. The electricity on entering this bar should have been forced to follow a tortuous circular route; its momentum was, however, too great for the molecules, and they elected to turn, allowing the electricity to pass in a straight line through the bar. Thus, in the first instant, magnetism was the master directing the course of the current; in the last it became its servant, obeying by turning itself to allow a straight path to its electric master.

SUPERPOSED MAGNETISM.

It is well known that we can suppose a weak contrary polarity upon an internal one of an opposite name. I have been enabled thus to superpose twenty successive strata of opposite polarities upon a single rod by simply diminishing the force at each reversal. I was anxious to prepare a steel wire so that in its ordinary state it would be neutral, but that, on giving it a torsion to the right one polarity would appear, whilst a torsion to the left would produce the opposite polarity. This I have accomplished by taking ordinary soft steel drill wire and magnetizing it strongly whilst under a torsion to the right, and more feebly with an opposite polarity when magnetized under torsion to the left.

The power of these wires, if properly prepared, is most remarkable, being able to reverse their polarity under torsion, as if they were completely saturated; and they preserve this power indefinitely if not touched by a magnet. It would be extremely difficult to explain the action of the rotative effects obtained in these wires under any other theory than that which I have advanced, and the absolute external neutrality that we obtain in them when the polarities are changing we know, from their structure, to be perfectly symmetrical.

I was anxious to show some mechanical movement produced by molecular rotation, consequently I have arranged two bells that are struck alternately by a polarized armature put in motion by the double polarized rod I have already described, but whose position, at three centimeters distant from the axis of the armature, remains invariably the same. The magnetic armature consists of a horizontal light steel bar suspended by its central axle; the bells are thin wine-glasses, giving a clear musical tone, loud enough, by the force with which they are struck, to be clearly heard at some distance. The armature does not strike these alternately by a pendulous movement, as we

may easily strike only one continuously, the friction and inertia of the armature causing its movements to be perfectly dead beat when not driven by some external force, and it is kept in its zero position by a strong directive magnet placed beneath its axle.

The mechanical power obtained is extremely evident, and is sufficient to put the sluggish armature in rapid motion, striking the bells six times per second, and with a power sufficient to produce tones loud enough to be clearly heard in all parts of the hall of the institution.

There is nothing remarkable in the bells themselves, as they evidently could be rung if the armature was surrounded by a coil and worked by an electric current from a few cells. The marvel, however is in the small superposed steel magnetic wire, producing by slight elastic torsions from a single wire, 1 mill. in diameter, sufficient force from mere molecular rotation to entirely replace the coil and electric current. (Experiment shown by ringing the bells by the torsion of a small $\frac{1}{16}$-in. wire placed 4in. distant from bell-hammer.)

CORRELATION OF FORCES.

There is at present a tendency to trace all physical forces to one, or rather a variation of modes of motion. In my last experiment the energy of my arm was transformed in the wire to molecular motion, producing evident polarity; this, again, acted upon the ether, putting the needle-hammer into mechanical motion. This by its impact upon the glass bells transformed its motions into sonorous vibrations; but this does not mean that we can convert directly sonorous vibrations into magnetism, or *vice versa.*

Let us take this soft iron rod; it seems quite neutral, although we know that the earth's magnetism is trying to rotate its molecules to north polarity at its lowest extremity. We now put it in mechanical vibration by striking it gently with a wooden mallet; the molecules at once rotate, and we have the expected strong north polarity. Let us repeat this experiment by employing heat, and here, again, at red heat an equally strong north polarity appears.

Again we repeat, and simply pass an electric current of no matter what direction; again the same north pole appears. Thus, these forces must be very similar in nature, and may be fairly presumed to be vibrations, or modes of motion, having no directive tendency, except a slight one, as in the case of electricity; for the same three forces render the rod perfectly neutral, even when previously magnetized, when placed in a longitudinally neutral field, as east and west.

Motion of the molecules gives rise to external magnetism to a rod previously neutral, or renders it neutral when previously magnetized; in other words, it simply allows the molecules to obey an external directing influence; the only motion, therefore, is during a change of state or polarity. If there is constant polarity there is no consequent motion of the molecules; in fact, the less motion of any kind that it can receive, the more perfect its retention of its previous position; consequently, constant magnetism cannot be looked upon as a mode of motion, neither vibratory nor rotatory. It is an inherent quality of each molecule, similar in its action to its chemical affinity, cohesion, or its polar power of crystallization. A molecule of all kinds of matter has numerous endowed qualities; they are inherent, and special in degree to the molecule itself. I regard the magnetic endowed qualities of all matter or ether to be inherent, and that they are rendered evident by rotation to a symmetrical arrangement in which their complete polar attractions are not satisfied.

Time will not allow me to show how completely this view explains all the phenomena of electro-magnetism, diamagnetism, earth currents—in fact, all the known effects of magnetism — up to the original cause of the direction of the molecules of the earth. To explain the first cause of the direction of the molecules of the earth would rest altogether upon an assumption as the first cause of the earth's rotation, and of all things, down to the inherent qualities of the molecule itself.

The mechanical theory of magnetism which I have advocated seems to me as fairly demonstrable as the mechanical theory of heat, and it gives me great pleasure to have been allowed to present you with my views on the theory of magnetism.

TRANSMISSION OF POWER BY BELTS, CORDS, AND WIRE ROPES.

By GEORGES LELOUTRE.

From Abstracts of the Institution of Civil Engineers.

A former abstract of a paper by the author upon this subject gave a summary of his researches; and these have since been detailed in the present extensive essay, to which was awarded in 1881 a gold medal offered to competition.

Having found that so-called practical formulas and rules are seldom of much value, in consequence of being made too general, the author twenty years ago began experiments of his own, which he has recently extended and rendered more complete. In his two first chapters he examines the facts relating to the stretching, elasticity, breaking, and slipping of cords and belts. Most of these facts run counter to the notions generally entertained. Above all, the influence of *time* on the elongation and breaking strain of belts, cords, and webbing, cannot be neglected.

The experiments on the elongation, elasticity, and breaking strength of belts were all made with dead weights, as described in the former abstract, so as to avoid the error arising from friction in testing by any lever machine. Detailed particulars are given of thirty experiments, the results of which are analyzed. The elastic stretching of leather belts under tension is by no means proportional to the strain: the amount of stretch increases much less rapidly than the strain, or, in other words, the modulus of elasticity rises with the strain. The resistance to stretching is greatest when the strain reaches about 850 lbs. per square inch of sectional area in leather belts; and in india-rubber and webbing at a rather lower strain. However rapid the stretching during the first hour, a considerable further elongation takes place when the strain is continued for two or three weeks; but two or three days' continuance is long enough to give a sufficiently accurate result for practical purposes.

In respect of elasticity, belts are never in practice at rest or relaxed long enough to recover wholly from their stretching. Even when at rest, a belt that remains on its pulleys continues to sustain throughout its length a strain equal to the mean between that on the driving and that on the trailing span when running. The elasticity of ordinary new leather is remarkable: a thong of very common leather, breaking at 2,280 lbs. per square inch, stretched as much as 22 per cent., of which it recovered at once rather less than half; and after fifteen months' rest it had returned to exactly its original length. There appears indeed to be no true permanent set for leather; it stretches to the same extent whether broken under a rapidly increasing load or under one applied for a long period, but in the former case it recovers more readily than in the latter.

The breaking strength for belts of all materials is from half as much again to twice as much when the load is increased up to the breaking strain in a few hours, as when that strain is slowly reached in the course of five or six months. In ordinarily good leather the breaking strain when reached in an hour or two will be as high as 4,300 to 4,800 lbs. per square inch; but under loads slowly applied it will be only 2,850 lbs., and even less. India-rubber is rather weaker. Hence any results arrived at in trials that last only a few hours must be reduced in the above ratio for practical use. Though the strongest leather is not that which stretches least, yet in practice the mistake is generally made of looking for belts not to want tightening up too frequently, without regard to whether they are working at one-third or at one-sixth of their breaking strength. For a belt to last, however, the latter consideration is the more important: the leather employed should be the strongest and most elastic; and frequent tightening may readily be obviated by the simple expepedient of subjecting a fresh belt for some days before using it to a tension of from 1,050 to 1,450 lbs. per square inch. Some belts are made of leather that has been compressed in thickness by calendering; but the leather recovers its

original thickness, just as it does its shortness after stretching. The tension which the author has been led to adopt for leather belts in practical working is from 640 to 780 lbs. per square inch, instead of the much lower strains generally recommended of only 200 to 350 lbs. The tensile strength does not appear to be impaired by repeated breakages. Hence the permanent load on belts may be made high, without fear of overstraining them or impairing their elasticity, their greatest strength being apparently developed under a tension of about 850 lbs. per square inch. Trying annealed iron wire, by way of analogy or contrast, the author found its breaking strength unaffected by the time occupied in testing; the first fracture diminished its elasticity, when thoroughly annealed, but not its strength; it undergoes sudden elongations after several days, to a greater or less extent according as the load is heavier or lighter; and lastly, under a load applied for a length of time, the stretch on breaking is about a third of what it is when the wire is broken in only about an hour's testing.

As to slipping, a very common mistake in practice is to suppose that the coefficient of friction, or ratio between the tensions of the driving and trailing spans of a cord or belt, increases with the size of cord or breadth of belt or diameter of pulley. But so long as the arc of contact on the pulley contains the same number of degrees, the size of cord, breadth of belt, and surface of contact, have absolutely no effect on the ratio between the two tensions at the moment when slipping is on the point of taking place. On this head the author's experiments are conclusive, ranging as they do from sewing thread up to hemp and cotton cords of $1\frac{1}{4}$ inch diameter, and from leather thongs only $\frac{3}{8}$ inch wide up to belts 12 inches broad, with pulleys of from 8 inches to 8 feet diameter, on which the surface of contact varied in the ratio of 1 to 500, while the arc of contact ranged from half a turn (180°) up to $3\frac{1}{2}$ turns. What does modify the coefficient of friction for belts is their greasiness, and especially the degree of polish of the pulley-rims on which they run.

Throughout the author's experiments the coefficient of friction was found to be nearly constant: it ranges from 0.070 to 0.075 for new cords, and from 0.090 to 0.180 for new leather belts that have not run long enough to get saturated with swarf; for old belts covered with a layer of dirt the coefficient is much higher; and when the pulleys are imperfectly polished it may rise to 0.300 and upwards. The coefficients commonly assumed are at least twice as high as these. When the pulley-rims are rounded over slightly convex in transverse section, the friction is rather less than when they are flat; for pulleys above 6 or 7 feet diameter the difference is immaterial. For well-greased belts the coefficient of friction diminishes as the tension increases; but this is only because the grease gets partly squeezed out when the belt runs tighter over the pulleys. The experiments were made by keying a pulley fast on a fixed horizontal shaft, and hanging a belt over it with equal weights at each end, and then gradually increasing the load on one end till the belt slipped. The trial must be continued long enough, because a load insufficient to cause in a few seconds any perceptible slip will produce a considerable slip in the course of hours. On the other hand, as the steady experimental pulley is free from the jar that occurs in all running pulleys, the adhesion is higher upon it than in actual practice. Moreover at high speeds of from 2,000 to 6,000 feet per minute a belt draws air in between itself and the pulley-rim, whereby the adhesion is impaired; this can be obviated by slotting holes at intervals through the rim, parallel to its edges, and the belt will thereby be kept running straight on the pulley.

The particulars and results are given in detail of eight experiments with cotton cords, ten with hemp cords, twenty-one with leather belts, and one with an india-rubber belt. From these experiments the author is led to adopt the following minimum values for the coefficient of friction, which give the corresponding ratios for the tensions of the driving and trailing spans when on the verge of slipping, the arc of contact with the pulley being 180° in each case. For new cotton or hemp cords, coefficient 0.075; ratio of tensions 1.27 to 1.00 for pulleys with flat rims, to 1.45 to 1.00 for pulleys with semicircular grooves or with V grooves having an angle of 80°, the nip-

ping of cord in the groove being neglected. For ordinary new leather belts, coefficient 0.155, ratio 1.67 to 1.00. For new india-rubber belts, and for well-greased old leather belts, coefficient 0.200, ratio of tensions 1.90 to 1.00. No account is taken of extra adhesion from the pulley-rims being imperfectly polished or merely turned, because in working they gradually become more and more polished by the stretching of the belt upon them under the load.

The practical examples, by which in his third chapter the author illustrates the application of his results to actual belt gearing, comprise the transmission of 42, 80, 280 and 700 horse-power by leather belts, and of 60 horse-power by an india-rubber belt: with regard to each of which the whole of the particulars are fully detailed and analyzed, including the description and strength of the belts, the loads on the bearings of the flywheel and pulley-shafts, the strength of the flywheel, the mode of joining the ends of the belt, and the relative advantages of cords and belts. Owing to the damaging effects of centrifugal force on lap-jointed belts, preference is given to butt-joints stitched with either one, two, or three thongs, through four rows of holes spaced zigzag, the stitching being so done as to range the thongs all parallel to the edges of the belt on its inner face, and diagonally on its outer; the thongs should be of very supple leather, such as the white *kronenleder* (crown-leather) obtained from Switzerland. Attention is drawn to the importance of flywheels being properly proportioned to the trains of toothed gearing they control, the flywheel being often made too heavy. The construction and strength of pulleys with curved arms is examined at much length. In regard to the relative friction with belts or cords and with toothed gearing, it is shown that theoretically the advantage is always more or less on the side of belts or cords; while a practical confirmation of this conclusion is furnished by the instance of a spinning mill, in which toothed gearing driving 18,000 spindles was replaced by belts, with a saving of 20 per cent. in friction or 3½ per cent. on the effective driving power transmitted; and in no case do belts practically cause more friction than toothed gearing. The particulars are furnished of three examples where driving by belts did not prove thoroughly successful; and the conditions are pointed out which led to the less satisfactory results.

The fourth and concluding chapter treats of the loss through friction and other dead resistances in transmitting power through great distances by means of wire ropes. This loss the author considers can be brought down as low as 30 or even 20 per cent. in transmitting power by ropes through distances of 6 to 7 miles and upwards. While electric transmission may be employed in connection with great mountain waterfalls, water-power nearer at hand may be utilized advantageously through ropes. The heavy outlay in each case is the same, being that incurred in constructing the necessary leats, or head and tail races, and in erecting the hydraulic motors themselves. The coefficient of friction for an iron wire rope in a round bottomed pulley groove that is lined with leather standing an end is found by the author's experiments to be 0.220 for half a turn round the pulley. From experiments at a spinning mill at Oberursel, Nassau, to which water-power is transmitted through iron wire ropes from a distance of 3,150 feet in eight spans of about 394 feet from pulley to pulley, it was found that, when using the maximum quantity of water, equivalent to 175 HP., the useful effect, tested by friction brake at the mill, was not more than 99 HP., or only 56 per cent. The aggregate loss of power, through friction of pulley bearings, stiffness of ropes, and resistance of air, ranged between 11½ and 12 HP. for seven of the above spans together. The ropes were 0.59 inch diameter, and ran at about 55 to 60 miles an hour in ordinary working; the pulleys were 14.8 feet diameter, the weight of each with its cast iron axle being about 28 cwts. From these experiments the author deduces 0.090 as the coefficient of friction for the pulley bearings, 0.092 as the coefficient of stiffness of the iron wire ropes, and 0.000451 as the coefficient of air-resistance to the pulley arms. These coefficients are discussed, and confirmation is obtained for them from a comparison with those hitherto accepted under different forms from recognized authorities upon the subject.

ARRANGEMENTS FOR THE PREVENTION AND EXTINCTION OF FIRES IN THEATRES.

By ERNEST A. E. WOODROW, A.R.I.B.A.

From the "Journal of the Society of Arts."

Theatres should be entirely fire-resisting, and have nothing in their construction that will readily ignite, so that the ordinary methods of extinguishing fire will suffice. This can be attained by giving due consideration and study to the planning and the materials of which the building is constructed. How these buildings can be planned and constructed, carrying out a safer system than at present, is what I would wish to try and point out in as brief a manner as possible, touching, it is feared but imperfectly, on only some of the most important points.

When the principal material employed in the construction is thin wood, as is, or perhaps I should say was, so often the case, no possible hope of safety could be entertained either for the building or the public frequenting it.

That a theatre can be made safe in spite of the special dangers from the class of business carried on in it, there cannot be a doubt in the mind of any one who has given attention to the subject. Like every other class of building the special risks attending it can only be known by becoming thoroughly acquainted with the business carried on in it, and the special mode of conducting such business, with the accompanying dangers. Until this is ascertained, no one can possibly plan a theatre to avoid these risks, and ensure the safe and easy working of the house.

A theatre, of all buildings, should have a place for everything, and everything in its place; and it is necessary to know what this everything is before the place for it can be provided.

The first step to be taken is to provide such means in the planning of the house as to enable the people to get out of the building in the shortest possible time, at the slightest provocation, in every way lessening the dangers from panic. Then, the construction of a theatre, and the materials used, should be such as to render it wholly fire resisting; this can be aided greatly by the manner in which the various departments are placed with relation to each other.

As a theater can be made fire resisting no house should be allowed to remain open which is not so. It is no good to patch up the old wooden edifices with sheet iron and pugging, and expect that the buildings will be any the safer. If such theatres still exist in any part of the kingdom, they should be closed, even if the loss is sustained by the public themselves. When the slightest fire commences in one of these flimsy structures, as was seen at the fire at the Alhambra, no efforts, either from external or internal aid can possibly extinguish it.

Judgment in the choice of materials with which to construct the building, requires such great care and study that too much importance cannot be placed on this branch of the subject. The materials employed for the erection of places for the assembly of the public, whether for amusement, instruction or devotion, must be, in every sense of the words, "the best of their several kinds." The scantlings, or thicknesses, must be far in excess of what would appear to be necessary for the actual or present work which they have to perform, so that they may resist any shock or pressure that may from any cause be brought on them.

In short, a theatre must, of necessity, in comparison with other buildings, be exceedingly costly. In this I refer only to the structural portions, leaving all decorations out of the question. In dealing with buildings where human beings are "packed," surely more care should be bestowed upon their construction than upon warehouses or factories. But as long as cheap theatres are erected danger will be rife.

Planning and Construction for Prevention of Fire.

No theatre should be allowed to stand

that is "hemmed in on all sides with a narrow entrance, as a frontage in a public thoroughfare sufficient to carry a flaming gas device." The dangers accruing from the surrounding property are often as great as those in the theatre itself. In no case should people be allowed to live and sleep in or about this class of building; the many risks necessarily attending them through their own special trade should not be increased by the dangers generally to be met with in the dwellings of the lower class; and a building, or part of a building, not designed for the special business of a theatre, should never be used for such purposes, as it is nearly sure to be unfit for them.

The site should be isolated on all sides, wide streets running all around the building; but as this is difficult to obtain in crowded cities, a theatre might be designed with comparative safety having one side touching other buildings. To obtain perfect safety a site isolated on all sides should be insisted on.

The most importent item in the planning is what might be called the party-wall system, making every division of a theatre a separate building, with as few openings connecting the various sections and sub-sections as the smooth working of the house will allow. Commencing with the back of the building, I should place the workshop section, divided from the main building by an open area; then the stage, with dressing-rooms and wings on either side; then, of course, follows the auditorium the corridors, the staircases, and the offices and saloons. Each of these many sections must be divided from the other, vertically, by strong brick walls, with the openings closed by fire-resisting doors, and, horizontally, by fire resisting floors.

The various divisions within each section should be again separated by brick walls and strong, fire-resisting floors, so that, should one room be burnt out, no other part of the building would suffer. This system applies throughout the whole building.

The position of the workshops should be such as to ensure an entirely separate building, connected with the theatre by one opening only, which should be closed by a double fire-resisting door, which door should on no account be allowed to open during a performance. Should space permit, the open area should be made 12 feet wide between the theatre proper and the workshops.

Where no area can be obtained, a thick brick wall passing through and above the roof should divide the workshop section from the stage section.

All stores for scenery, properties, &c., not in immediate use should be in this building.

The painting gallery might be placed over the workshops, getting a top studio light, which should be protected by strong wire guards against falling sparks or materials. There is no special danger from scene painting, oil not being the medium used, as is sometimes supposed.

The stage is too often used as a carpenter's shop. This should never be allowed; the many dangers thus incurred need no pointing out; yet it is strange that seldom is a special room provided for the carpenters. The work in some houses was carried on over the auditorium ceiling, but this is happily stopped. A special workshop should always be provided.

Dressing-rooms might be placed on either side of the stage for males and females, being divided from the stage horizontally by brick arches, and vertically by brick walls. Fire-resisting staircases and separate exits into the street are necessary for each wing, as also for the workshop.

The fire places, where provided in the dressing-rooms, should be protected by tall wire guards. A complete system of heating throughout by hot-water pipes is, however, preferable to open fireplaces.

The stage-floor and sliders must of necessity be of wood, for setting the scenes, but much on the machinery might be made of iron, keeping somewhat the same forms now used in wood, and making a stiffer stage, which could be more easily manipulated.

On a level with the stage floor there must be ample room for scene docks, for storing the scenes in nightly use, while shifting from one set to another. The mezzanine and cellars should be used only for the machinery for working the stage, and on no account should the stowage of rubbish or scenery be allowed here—it never would if proper provision were made for it elsewhere. It is here

that the stage carpenter does such infinite harm with his match-board erections, after the building is out of the hands of the architect.

The band and other rooms are at times but portions of the mezzanine, match-boarded off as if they had been forgotten when making the plans (which is more than likely). Proper accommodation must be supplied for band, band master, stage-manager, firemen, bill-sticker, property-master, &c., &c.

The gridiron above the stage must be made sufficiently strong to carry the weight of the cloths, &c. Cases have been known where it has given way under the weight of the scenery, and let everything in dangerous confusion down on to the stage. The construction of the gridiron, flies and flyrails should be of iron. Communication is necessary from the flies to the stage, to enable the flymen to escape.

The stage should be divided from the auditorium by a thick, solid brick proscenium wall, which wall should go between the orchestra and mezzanine, and be arched over the opening, passing through and above the roof. There need only be one opening in this wall, in addition to the large or proscenium opening, namely a pass door from the stage to the auditorium.

A separate fire-resisting passage way should be provided for the exit of the orchestra, so that the musicians may avoid passing either through the audience or under the stage to gain the street.

The stage should undoubtedly be cut off from the auditorium by some sort of fire-resisting or smoke-proof curtain. The failure of some of the iron curtains used on the Continent and in America has shown that they are not always to be relied on, but they must be of some use in retarding the progress of the flames. A double thick felt or cloth curtain, made bag shaped, and a water spray along the top that would damp the curtain whenever it was lowered, suggests itself as a method for shutting off the stage. Water curtains have been proposed, but as these could not be periodically tested on account of the destruction of property that would ensue, they cannot be recommended. Whatever is adopted must be in constant use, for anything designed to act only in case of need, or upon the outbreak of fire is often liable to fail at the very moment when it is most needed. Everything in and about a theatre must be always in use to be of any good. Where automatic appliances are provided, people are apt to put such faith in them that they ignore the ordinary and essential means of fighting against fire, and become careless of the importance of the great danger. An "emergency" curtain coming down unexpectedly in the middle of the performance would be but the signal for a panic. Appliances requiring the presence of the flames which they are supposed to extinguish before they can act, cannot be too strongly condemned.

I repeat, and cannot insist upon it too strongly, all appliances must be made so that there will be no way of using them nightly. Therefore the smoke-proof curtain and the painted act drop should be made to fall always together.

The scenery should be protected by applying some of the numerous solutions recommended by our chemists, and all drapery should be similarly treated.

The woodwork in and about the stage should be periodically painted with asbestos paint, or other fire-resisting liquid, and no precaution left untried to mitigate the danger from fire.

In dealing with the stage, we have to contend with that portion of the house where there is the most danger from fire, the immense amount of gas used nightly, and sometimes in a careless manner, as pipes are being constantly connected and disconnected during the performance, causing small escapes near naked lights, makes one wonder that accidents occur as seldom as they do.

All lights must be protected by wire-guards, and an arrangement should always be used whereby the gas is automatically cut off at the place where the union is made during the process of shifting various battens, ground-lights, &c.

The gas should be under the control of a practical gas man, with a sufficient staff of subordinates. This man should be stationed at the gas plate, which is fixed on the stage during the performance, on which plate each cock should be labeled indicating what section of the light it governs, so that no error can possibly be made, and the wrong part of the house put in darkness.

The mode of lighting up should be by the electric spark, and not by naked lights. The "flash" system should be applied to all battens and hanging lights, avoiding the use of the spirit, cotton, and cane moving among the scenery. When the electric light is used, many of the dangers of stage illumination will be done away with; yet great care will have to be taken in the manipulation of the light, which need not be touched on here.

The gas-meters should be placed in a specially prepared and ventilated room. The supply pipes must be of hard metal, visible, and coated to prevent corrosion. There should be a cut-off tap near the stage door, to turn off the gas from without in case of fire. Separate meters should be provided for every section of the house, and a double supply laid on to each. Every set of staircases, corridors, offices, dressing-rooms, workshops, as well as the stage and auditorium, should have a dual system of lighting.

Every burner should be protected by an incombustible guard, and fixed away from woodwork or inflammable material, with a metal flue over it. In the parts of the house frequented by the rougher class, the lights should be encased, or locked up, or placed out of reach.

Sun-burners are preferable to gasoliers; these must be periodically cleaned, and no woodwork fixed near them. Access should be provided to them from the roof.

Oil lamps should be placed about the buildings in all sections, in conspicuous positions, but out of the reach of the public, to take the place of gas on its extinction. Colza oil has been found preferable to any other. Red lamps, with the word "Exit" in white, should be placed over the exit doors. All lamps should be lit and in their places before the doors are open, and the gas, both on the stage and in the auditorium, should be lit before the audience is admitted.

Gas-burners fixed so that they can be tampered with are among the most prolific sources of producing fire. There should be no jointed brackets or swinging pendants; every fitting must be fixed, and all joints and appliances examined and approved before the house is licensed.

Proper precaution should be taken in the manipulation of the lime light, and the bags kept outside the buildings.

Provision for plenty of light should be made to enable the use of artificial light being discontinued during the day, thus avoiding one of the greatest risks in theatres, namely, the careless handling of lamps, candles, or matches. It is a frequent habit to drop the end of a semi-burnt match, and one to which great danger is attached. There could never be a greater mistake than making a theatre dark. The business could be better carried on if there were plenty of daylight, and the accumulation of the dirt of years would not then be suffered to remain unremoved, ready to flare up on coming in contact with the slightest spark. A theatre, for everybody's comfort, should be clean; but as long as it remains dark, it will be dirty and dangerous. Therefore, the removal of rubbish should be insisted on daily, or an external furnace provided in which it could be consumed.

The roof should have easy access from various points, and be provided with cat ladders, leading from the different levels, to enable firemen to get about with ease. There should be a parapet wall all round to protect the firemen. The construction of the stage roof should be of iron; if of wood, the constant changes of temperature to which it would be subject, and the enormous heat, would desiccate the trusses and rafters, and convert them into something little better than touchwood, which would readily ignite.

A better mode of constructing an auditorium roof could not be cited than that of the new Alhambra Theatre, where iron and concrete, with a covering of asphalte, are the materials used. The ceiling of the auditorium should be formed of fire-resisting materials, such as Jackson's fibrous plaster, and never of canvas. There should be no space over the ceiling available for store or workshop.

The several divisions of the audience should each have their separate entrances, exits, passages, corridors, staircases, saloons, lavatories, &c. The best method of planning this portion of the house, having in view the safety of the people, would be to bring everybody as near the level of the street as possible. To do this, place the dress circle on the street level, go down to the pit, and up to the upper circle and gallery. By adopting this method, the various sections of the audience would have a better chance of gaining the street, the distances being

more distributed. The fact of the building not being so high as it would be if the pit were on a level with the street, would give a better chance of aid in case of fire; and as the parts occupied by the administrative officers need not be carried so high as the main building, an intermediate roof could be obtained, whereby the principal roof could be easily reached from without. The people in the pit, being below the level of the street, would not be in any danger, as in going upstairs a crowd is not likely to stumble, there not being the same risk as when coming down stairs.

Each section of the audience should have two entrances and exits, one on each side of the house, such exits and their approaches leading directly into the street, and these should be used only by that section of the audience for which they are designed, there being no pass-doors or emergency exits leading from other parts of the house into them. A door that is known as an "emergency door" is only a trap; when opened, it, as a rule, leads into a corridor or staircase already full of people from another part of the house. All exits must be entrances, and entrances exits, and used nightly.

Staircases and passage-ways should be from 4 ft. 6 in. to 5 ft. wide. Where this width is insufficient for the number of people, an extra staircase should be provided rather than additional width being given beyond the 5 ft. The corridors immediately outside the various tiers should be of sufficient width to take the people occupying such tiers without crushing. These corridors must be divided from the auditorium by brick walls, and the openings fitted with fire-resisting doors.

There should be no winders or steps at half landings in the staircases, as all such are dangerous in a moving crowd. The flights should not be of more than eight or ten steps, and the treads and risers should be of easy and uniform go throughout. All steps and landings must have at least $4\frac{1}{2}$ inches bearing on solid brick walls at both ends, and arches should be turned under the landings.

Strong hand-rails, on brackets built into the walls, should be fixed to both sides of all flights of steps and landings, leaving a space of three inches clear between the wall and the hand-rail. To acquire this, a chase should be cut in the wall, so as not to lessen the width of the staircase or passage-way by the projection of the hand-rail.

No single step, or flights of two or three, should be admitted, slopes should take their places.

The private box staircases should be made as important as the other staircases, with exits into the street, and communication at each level. As a rule, they are narrow or corkscrew staircases, only available for the private boxes.

There should be no unshipping of barriers; they should be made permanent, and hung so as to open outwards, and close against the wall.

No pay-box or barrier should be placed to obstruct the exits; the movable box so often seen should be abolished, and the pay-box made part of the permanent building.

All doors and barriers must be hung so as to open outwards, and close against the walls, the larger doors being hung in two folds. The fastenings on the doors used by the public should be such as to allow them to open the doors from the inside with ease. Locks are bad, as keys are seldom forthcoming when most required. The danger attendant upon the ordinary barrel-bolt was terribly illustrated in the case of the Sunderland disaster. It is apt to slip and catch in the floor, fixing the doors. A fastening is wanted that will enable those inside to get out, while it will at the same time present an effectual barrier to those outside. This has been provided by an invention known as "Arnott's patent bolt," in which an ordinary spring square bolt has the lower portion knuckle hinged. Pressure on the inside will cause this portion of the bolt to leave the socket, and become parallel with the floor, thus allowing the door to swing both ways. Pressure from the outside will only tighten the bolt. What are now known as "emergency" doors are too often found locked, and worse than useless.

If the public were acquainted with the means of getting out of a theatre, there is no doubt they would feel safer when visiting these places of amusement. A great number enter with the idea that they could never find their way out if they wanted; this is not to be wondered

at, considering what some of these entrances are, and that the entrances are not always the exits, and the exits not always used nightly. Everything should be done to inspire the audience with the idea that they could save themselves without hurting others in case of accident. To do this they should be able to find their way easily about the house. Several ideas to attain this suggest themselves—placing ample notices on walls and doors, such as "Exit;" "This way out;" printing the plan of each section of the house separately on the programmes; placing large plans of the house in conspicuous positions; but above all, simplicity and uniformity in the plan at the first onset. Place the exits where they will be easily seen, and make both sides of the house as nearly alike as possible. Notices should be painted on lavatory, saloon-doors, &c., to distinguish them from exit doors. All notices should be painted in luminous paint. Never should such notices as "In case of need," "Exit in case of fire," "In case of panic," "Emergency," "Alarm exit," be seen; they only suggest danger to the people, and everything should be done to intimate safety and avoid panic among the nervous visitors to theatres.

All seats should be numbered, and the house licensed to hold that number, and no more admitted under penalty of heavy fines to manager and visitor alike, then the gangways would be left unobstructed; but until they are both equally fined, the passages will be blocked by people standing or seated on loose chairs. All seats should be fastened to the floor, and made to tip up, to allow more room between each row for exit.

As far as the contents of the auditorium are concerned, it may be presumed that it is impossible to do without carpets, curtains, and stuffing to the seats, otherwise there need be nothing inflammable in the furniture.

The floor should be laid with blocks of hard wood, over the fire-resisting floors, for comfort.

As many bodies which are incombustible under normal conditions become inflammable at a high temperature, every means should be taken to keep a theatre cool, adding to the health, comfort, and safety of all. When heat is much concentrated, it makes substances highly inflammable, which might at a low temperature be simply combustible; it is therefore necessary, to prevent fire, to provide proper ventilation in a theatre. How often is this done?

The stage should be well ventilated, and at the same time there must be no draught to cause the scenery to wave about. Metallic shafts, with gas jets burning in them, fixed in several places above the gridiron, would draw off the vitiated and heated atmosphere and smoke in case of fire; but should a fire break out, the upward draught would increase it to a very serious extent; but if the gas jets were turned out, and the proscenium curtain lowered, the draught would be greatly lessened.

Fresh air should be admitted to the auditorium as near the floor level as possible, being previously warmed. The number of inlet shafts should have some relation to the numbers occupying the seats, and the manner in which the vitiated air is drawn out of the building. Sunburners play an important part in extracting the foul air, but, in addition, every gas-burner should have over it a funnel-shaped flue, up which the products of combustion might pass. It must be borne in mind that perfect ventilation is imperceptible; but to acquire such ventilation has been found a hard task, therefore theatres have been left to take care of themselves, and in but few cases the slightest provision taken to render them little better than death-traps. Whether the mode applied be what is known as the vacuum or natural system, or the plenum or mechanical, seems of little moment, provided fresh air is continually admitted throughout the whole house. The number of deaths occasioned through breathing the foul, poisonous, and heated air of our theatres is far in excess of those caused by fire and panic. It would be as well if some of the numerous authorities which govern places of entertainment in this country were to turn their attention to this fact; but I fear the familiar adage may only too truly be said of theatre regulation, that "too many cooks spoil the broth." Large sums of money have been expended in providing means to avert dangers that *may* occur some day, while the fact that thousands nightly breathe the poison that will bring disease and untimely death with

it, even to the strong, is totally ignored. Lightning conductors should be fixed at various points outside the building.

Materials for Prevention of Fire.

The accepted idea of what is fire-proof is a very mistaken one. Materials that are incombustible are not therefore fire-proof; take iron and stone, both accepted legally as fireproof, and both among the first substances that will succumb to the influence of heat and sudden change of temperature. To give an idea how totally mistaken some are as to the fire-resisting qualities of materials, I have known lead suggested as a substance to be used to render floors fireproof. Lead, of all materials, is the most dangerous, and the most dreaded by the fireman.

The walls must be solid and very thick, well bonded into each other, of good sound bricks; bond timbers should not be admitted, but hoop iron bond should be used. Every opening should have an arch turned over it, the use of lintels, either of stone or wood, being discarded. The walls should be corbelled out to receive the floors.

The floors, where possible, should be supported on brick arches abutting against brickwork, but on no account against iron. When the floors are constructed of iron and concrete, the iron should be completely embedded in the concrete, and the concrete should have the aggregate of calcined material, such as broken bricks, clinkers, or broken pottery. The circles should either be constructed of iron and concrete, or of timber in large balk, and of the hardest description, such as elm or oak, which should be thoroughly protected from the action of fire by thick coatings of plaster; gypsum, or plaster of Paris, is well adapted for this purpose.

Where iron columns are used, they should be protected by a thickness of fire-resisting plaster or cement, held to the columns with a good key. Strong posts of the harder woods would suffer less from the changes of temperature than iron, but their thickness would destroy a good deal of the sighting.

The ordinary thin iron doors are of no use to resist fire. If iron doors were placed on both faces of the walls the space between might be filled up with some wet materials to keep them cool; but it would be a very difficult task to do this to every door in a theatre. Thick oak doors would resist fire for a long time. Wooden doors, lined with sheet iron or zinc, would be more effective than the thin iron doors so often met with; none of these, however, would be *fire-proof*, although *fire resisting* to a certain extent. A perfect fire-resisting door could be made on the same system as safe doors, having an inner case of iron packed with sawdust and alum, surrounded by a strong, well-bound and well-hung outer case. These would be heavy and expensive, and as all fire-resisting doors must be hung to close automatically, they would be dangerous; but they should be fitted to divide the greatest risks, such as the workshop section from the stage, the stage from the auditorium.

Steps and landings should be made solid, of approved artificial stone, fire-clay, or concrete, whose aggregate has already been burnt. Stone should be avoided, as, in the words of Captain Shaw—a man whose opinion on such subjects is the best in the world—it yields to fire more rapidly than any other material, is the most dangerous of all materials, as at sudden changes of temperature it cracks, leaving a passage for smoke.

That unprotected iron is unsafe, owing to the risk of fracture, and the loss of strength attendant upon great heat, is a fact well known, and as it is sometimes applied, it is a source of great danger, assisting in the destruction of the building, as its contraction or expansion will thrust out or pull down the walls, and even when covered with cement, it will suffer in great heat. Wood is only a dangerous material when used in thin slices. "It will withstand a powerful dead heat upon its sides for an indefinite period without igniting, unless transverse sections of the fibre, such as a knot, presents itself to the action of fire." If used in large balk of the harder kinds, and protected with plaster, it is infinitely safer than naked iron.

The use of plaster as a fire-protecting agent I would strongly advocate; it is light, and resists fire for an indefinite period.

It would perhaps be as well to enumerate some of the many causes from which fires in theatres have originated and become fatal, before considering the last

part of our subject, namely, the extinction of fires.

Bad arrangement and planning of the various sections, and not making each an independent fire risk, and not providing separate accommodation for each department or trade.

Danger from contiguous houses, and from people living in and about the theatre.

Bad judgment in the choice of materials, and bad or faulty construction.

Foul or imperfect flues.

Darkness and dirt, and keeping rubbish, shavings, &c., on the premises.

Smoking in the theatre proper.

Overheating through lack of proper ventilation.

Unprotected gas-lights, and escape of gas from imperfect fittings.

Upsetting oil lamps.

Using matches or other naked lights.

Imperfect system of electric lighting.

Accumulation of heat round the sun-burner, and not cleaning same.

Carelessness in the manipulation of the stage during a performance.

The use of firearms, fireworks, and colored fires.

The want of a properly organized fire watch, defective fire appliances, and lack of water.

Carelessness among workmen, such as carpenters and plumbers.

Lightning, concentrated rays of the sun by means of lens, spontaneous combustion, and incendiarism.

Extinction of Fire.

When a building has been constructed that will in every way retard the spread of fire and panic, it should be considered how, should the fire, in spite of all the precautions, occur, it could be most effectually coped with.

A theatre, from the nature of its business and contents, cannot be *fire-proof*, although fire-resisting; but there is no reason why fires should not be localized and burn themselves out in the department in which they originate. Every means, therefore, should be taken to extinguish fire. Water is the element to overcome fire; it is cheap, and can be obtained in large quantities, and if there is some at hand when a fire first breaks out, a jug-full, judiciously used, would prevent the loss of much life and property.

As regards fire appliances, there should be an unsparing supply of fire-buckets, always full of water, in all parts and sections of the building; more good can be done with these, if used in time, than any elaborate appliance that may come into use when the fire has got a hold. These buckets should be made conspicuous, labeled "fire-buckets," painted red, and never allowed out of their place. Hand-pumps, with and without pails, should be distributed about the building, with a few chemical engines. Hydrants should be mounted on the rising main on every floor, in every section, and every 40 feet apart, having the hose "married" and ready for action. All proper tools and implements should be near at hand, wet sponges, wet blankets, hatchets, axes, &c., &c., being distributed about the stage and other parts. There should be a cock on each hydrant to fill buckets from. Hydrants should also be placed outside the building, and on the roof.

All fire appliances in these buildings should be periodically tested by the authorities; for the lack of this they are too often, on an emergency, found to be useless. The pattern of the appliances should be similar to that of the brigade of the town in which the theatre is situated, so that the theatre and town appliances may be used indiscriminately.

Ladders should be fixed from the roof to within 20 feet of the ground, where external aid can easily reach them. Iron balconies should be provided to windows.

It seems almost needless to say that there should be a sufficient supply of water, at a pressure strong enough to reach the highest part of the building. In towers formed at a height above the roof, there should be large water tanks, as a secondary supply, supposing the main failed at any time, but too much reliance must not be placed on tank hydrants. Experience has taught us that the tanks are too often empty, or only partly full, owing to the want of a constant supply from the water companies.

So much has been said upon the desirability of employing brigade firemen, well versed in their business, in lieu of the, in in more senses than one, "theatrical fireman," that I need not repeat the arguments in favor of the brigade men. Two

trained firemen should be in charge of the house from an hour before the performance till daylight, and two others should have charge during the day, all four being present when the house is open. The stage should never be left during the performance, and at the same time it would inspire the audience with confidence to see firemen walking about the auditorium. By the day watch the appliances should be cleaned and kept in repair, everything being tested every day at a fixed hour, say 6 p. m., just before the audience is admitted.

It should be the duty of the firemen to keep everything in working order, and they should be required to do nothing else. Imagine a stage without a responsible fireman, if, in the full swing of a pantomime, a small fire occurred. It is easy to conceive the confusion there would be among the numerous young and nervous people employed on the stage. The noise behind, even supposing the curtain to be down, would cause fear and panic among the audience, and a stampede might be the result. But if steady, experienced men, always ready for action, are employed, and the buckets and appliances are always in their places and in order, with plenty of water at hand, there need be no fear of fires on the stage. Yet there are many theatres in which the water supply is insufficient, the appliances imperfect, and no organized fire-watch in existence.

To extinguish fires on the stage, a suggestion has been made that a series of perforated pipes be fixed to the under side of the gridiron, or to the gas battens, governed by a series of stop-cocks on the stage. By this means the scenery that had not already ignited might be moistened, and the spread of fire stopped, but a great destruction of property would ensue. Far better get at the heart of the fire with a hand-pump or bucket of water.

Telegraphic communication should be held with the nearest fire-station. Too much reliance should not be placed on emergency fire-alarms. People are apt to become careless when they put their confidence in these appliances; they are also liable to act when no danger exists, especially in this class of building, where the temperature at times is so high; and, on the other hand, when most needed they may be out of order through disuse.

All check-takers and attendants should wear uniform, to be conspicuous, so that they may be better able to manage the people on an emergency. They should attend fire-drills, and be able to help the firemen when needed. For the same reasons it is well to have a policeman or two about the building.

To extinguish fire, provide good and sound appliances, plenty of water, and a good watch.

Theatres are luxuries, and to enter some of them one pays dearly, both as regards money and the risk of losing one's life. If we pay so highly, surely we should be better protected while there. But the system seems to be to work the house as cheaply as possible, and to pack as many into it as it will hold, at as high a price as they will pay.

After every consideration is given to the disposition and construction of the building, and it has been passed by the authorities, the architect, under whose supervision the house has been built, hands it over to the manager for the rest of its existence, except in rare cases where the architect receives a fixed remuneration for periodical visits—which should be the case everywhere. As a rule, the manager is a man of refinement and education, who will do everything in his power to protect the public and make the house popular. But for all that there should be a further continuous inspection supervising the management, as is being advocated by Mr. Dixon-Hartland in his bill now before the House of Commons. A staff of inspectors knowing the architectural arrangement, and the business peculiar to theatres, should be appointed, with power to visit the houses at all odd times, before, after, during the performance, in the day, and even in the middle of the night, unbeknown to the management. Reports as to the condition in which they find the house, and the way in which it is being worked, should then be made to the *one* recognized authority which should take the place of the many that now exist.

In theatres which at present hold certificates from the Metropolitan Board of Works as being structurally safe, fresh dangers may in a year or two arise, through alterations being made, per-

haps trivial in themselves, but to which some risk is attached. There are other matters requiring supervision besides structural defect, *i. e.*, ventilation, water supply, and the general management of the whole establishment. Until these inspectors are appointed, the public cannot be protected as they ought to be; on the other hand, it would be useless to make managers suffer from more official inspection, unless the men can be found to fill the posts who are qualified through previous experience in the *modus operandi* of theatre management and construction.

Once more I would strongly urge that the best safeguards against fire are good planning and construction, perfect ventilation, light, and scrupulous cleanliness; that the best means to extinguish fire are a good fire-watch and plenty of water; and that on no account should "emergency" appliances be relied on in a theatre.

DENUDATION BY RIVERS.

From "The Engineer."

Among the many important and complicated questions with which the practical hydraulic engineer has to deal, there are few more important, and few, perhaps, more complicated, than that of the discharge of water through open channels. Naturally, therefore, it has engaged the attention of engineers from an early period, and the formulæ laid down on the subject by Dubuat, Eytelwein and others date from centuries ago. Their experiments, however, were mostly conducted on channels of very small section, and it has long been recognized that to extend these to natural rivers, or even to channels of different dimensions, is to commit a grave error. Numerous formulæ have since been introduced, in the hopes of improving on the results of these early experimenters. Turning, for instance, to the well-known pages of Molesworth's *Pocketbook*, we find that the mere list of such formulæ occupies almost a page of small print, and that at least twenty authorities are there mentioned by name as having contributed to the subject. But as a striking commentary on their success a small table is given at the bottom of the same page, where four cases of actual discharge, varying from 24 to over 1,000,000 cubic feet per second are compared with the calculated results for the same conditions, derived from nine approved rules on the subject. The differences are very striking; in some cases they amount to nearly 100 per cent., and in many cases to at least 50 per cent. Nor is this a solitary instance. Major Cunningham, in his recent work on the Roorkee hydraulic experiments, arrives at very much the same result. Again, in papers published in our issue of November 1st, 1872, p. 293, the results given in the classical experiments of D'Arcy and Bazin are compared with the calculated results derived from several of these same formulæ, the object being to test the value of the formula obtained from theoretical considerations by the late Canon Moseley. Any one who will turn back to these figures will see divergences startling enough to prove that we must at least use considerable caution in adopting any formula for such purposes; and yet the conditions were here unusually favorable, as the experiments were carried on, not in the difficult and irregular channel of an actual river, but in an artificial conduit specially prepared for the purpose. In spite of these facts, which it is impossible to deny, nothing is more common than to see the most confident and offhand statements made as to the discharge of all sorts of rivers under all sorts of circumstances. To take one example, derived from the science of geology: It is frequently stated in geological works—as, for instance, by Mr. Alfred Wallace, and by Professor Geikie in his late admirable *Manual of Geology*—that a certain definite thickness of earth is removed from the surface of the land every year by the rivers which flow through it, and is by them emptied into the sea. The actual thickness, in thousandths of an inch per annum, is

given with all the confidence of an approved scientific fact. We have never been able to trace this statement to its original source, but we have no hesitation, as practical engineers, in pronouncing it to be altogether visionary. It is worth while to consider for a few moments what data would be requisite before such a figure could be laid down, even to the very roughest degree of approximation.

Of course, the only possible method of determining it lies in measuring, by some mode or other, the quantity of mud —or silt, to use the most general term— which all the rivers, say, of this country, carry into the sea during the course of a single year. What would any engineer do if he was given the commission of carrying out such an inquiry? He would have, in the first instance, to ascertain the mean annual discharge of every river or stream emptying itself into the tidal estuaries of Great Britain. It would be worse than useless to conduct observations upon these estuaries themselves, because it is perfectly well known that the silt suspended in such waters at any moment gives no evidence whatever as to the amount of silt which is conveyed into these estuaries from the uplands during each year or day. Therefore it would be vain, for instance, to compute the silt carried down by the Thames from observations taken below Tedington Weir; we must examine the Thames itself above that weir, and all the streams which enter into it lower down must be subjected to a separate investigation. Let us consider next what will be necessary in the case of any one of those streams. In the first place our engineer must have the means of measuring its discharge with sufficient accuracy on any particular occasion he may desire. We have said enough already to show that this is an exceedingly difficult matter, that he will be unwise if he relies even upon the best of the dozen or so of formulæ amongst which he may take his choice; and that he is, in duty bound, to make an accurate determination in the case of each river in order to take full account of local conditions. Let us assume that he has done so, and that he is thus able by a series of observations to ascertain with fair correctness the discharge taking place on any particular day. It is obvious that to measure this discharge for a single day only would be utterly futile. During a winter flood many rivers, even in England, will send down 50 to 100 times the water in an hour compared to that which dribbles over their bottom towards the end of a summer drought. Our engineer must, therefore, measure all the great floods which occur during the year he has selected, and must also take a large number of measurements both in the wet and dry seasons. This done, he must search carefully the meteorological records of the district—if he can find any—in order to ascertain whether this particular year may be taken as a fair average example, and if not, he must make such addition to or subtraction from his results as his own judgment shall direct him. Failing this, he will have no recourse but to renew his observations from year to year, until in the lapse, say, of a generation, a true average can be struck. At the end of this time, provided there are no indications of a progressive change in the climate and rainfall, he may fairly be allowed to state what the mean annual discharge of this particular stream may be.

But his work is only begun after all; it is not the quantity of water discharged which he is in search of, but the quantity of silt. He has to determine not only the number of cubic feet of water which has flowed through his channel in a particular year or a particular half century, but how much solid matter each of these cubic feet held in suspension while it passed. To do this it will by no means suffice to pick up a bucketful every time that he makes an observation, have it carefully evaporated, and weigh the residue which remains. We know scarcely anything of the laws of distribution of suspended matter within the waters of a stream. It may, indeed, be assumed that the quantity per cubic foot will be larger towards the bottom than towards the top of the current; but the law according to which this varies is quite unknown. All that we can be sure of is that this law itself will vary, probably very largely, with the depth of the current, with its velocity, and with the contour of the bottom, with the material of which that bottom is composed, and probably with many other local circumstances. It will not do, therefore, to trust to anything less than

the collection of a large number of samples, say 50 to 100, from all parts of the cross section, on each occasion when the discharge is measured, or at any rate, on each occasion when the river is in an abnormal condition. Suppose this to be done and the weight of silt per cubic foot at each of these places to be ascertained by the slow method of evaporation and weighing, then it will by no means do to strike an average of all the fifty and multiply this by the number of cubic feet discharged per hour; for the velocities at different parts of the cross section are very different, and this will clearly modify the results. Thus, if the velocity at the bottom is half that at the top, whilst the weight of silt per cubic foot is double, it will be seen that the amount of silt carried down per square foot of area at the bottom and at the surface will be really the same. Hence, we must know the average velocity in each of the fifty divisions, say into which our cross section has been partitioned off for convenience, and we must also know the average weight of silt per cubic foot corresponding to that division. Multiplying together each pair in these two series of numbers and adding the products thus obtained, we shall arrive at some sort of approximation towards the quantity of silt which our stream was carrying down per hour, on the day when this particular observation was taken; and the same process will have to be repeated for every one of the separate observations which have been described as being necessary in order to solve the problem of mean annual discharge. The experiments must necessarily be conducted over a considerable number of years, because it is quite possible that the effects of drainage, denudation, or other causes may produce a progressive increase or diminution of the average quantity of silt borne down, and of this it will be necessary to take account.

So much for our single river; we have now to perform the same task for every other river and stream, from the largest to the smallest, which empties into a tideway around the coast of our island. The smaller streams will no doubt, give less trouble than the larger, but they must by no means be neglected. We have no means at hand of estimating the number of such streams, but assuming that there is merely one for each mile of coast, it will be evident that it will be considerably over 1,000. Supposing, however, that the whole of these have been gauged, and the discharge of silt calculated in the manner just described, we may perhaps imagine that our engineer's task is at an end. Not a bit of it. He has to ascertain not merely how much solid matter has been carried into the sea per annum, but how thick a layer of solid matter has been subtracted from the land. Now, the quantity of the solid matter upon the land is being added to every year by the operation of certain very obvious causes, such as the falling of leaves, the decay of plants and animals, the application of foreign manures, &c. Possibly some one may object that organisms, whether plants or animals, can only build up their substance from materials already existing in the earth, but a moment's reflection will show that a large part of their substance is derived either from water or from air. It is precisely this decaying organic matter, lying, as it does, at or near the surface of the ground, which will be washed off in the greatest proportion by rain and by rills, and will so find its way into the rivers, and thence to the sea. Therefore, our engineer must of necessity do one of two things: he must either analyze carefully every ounce of silt recovered in his observations in order to ascertain beyond a doubt, first, how much of it is due to organic and how much to inorganic matter; secondly, how much organic matter was derived from the earth and how much from air and water; or, failing this, he must by some means or other calculate the whole volume of matter which has been added to the earth by the causes above mentioned, he must measure the quantity which remains at the end of that period, and he must subtract the difference—or rather the difference less that part of it which is due primarily to inorganic constituents—from the total amount which he has already ascertained to form the burden of the rivers as they fall into the sea.

We have, perhaps, said enough to show, however faintly and inadequately, the nature of the task which an engineer would have before him if he were set to ascertain the correctness of the figure which geologists quote so confidently, viz.,

the thickness of the layer of soil which is removed annually from our British Isles by the operation of what is called sub-aerial waste. A feeling of longing and regret steals over us as we close the record. What a pity that the determination of this figure is not a matter of paramount national importance to be settled at any cost! and what a pity that we ourselves are not given the responsible task of settling it! It would resemble one of those magnificent Chancery suits which an attorney of the old school was wont to regard with so much complacency and satisfaction; a suit which he could slowly administer during his life-time, and hand on to his children with his blessing on his deathbed, certain that it would remain as a sure and comfortable source of income to them and their children yet unborn.

And yet geologists quote this figure with perfect confidence, as if it was known to the 10,000th of an inch. They do more—they calculate on this basis the number of years which will elapse before Great Britain becomes a dead level, totally forgetting that the diminution of slope all over the country will wholly change the conditions of the problem. They do this in the name of science, and in the next breath inform us that science is measurement!

Our geological problem has detained us so long, even in the mere stating of it, that we have no space left to consider further the special engineering problem —that of determining the discharge of rivers—with which we set out. We hope, however, to return to it at no distant date, having perhaps said enough, even here, to show that it is not one to be settled off-hand, and without either reflection or research.

ELECTRICAL CONDUCTORS.

By WILLIAM HENRY PREECE, F.R.S., M. Inst. C.E.

Proceedings of the Institution of Civil Engineers.

I.

In no branch of engineering has the mutual dependence and reaction between practice and theory been more beneficial than in the useful appliances of electricity. Without theory the rule-of-thumb telegraphist would have been stationary. Without practice the electrician would have been a dreamer. The practical difficulties of telegraphy incited the physicist to trace out the laws that govern the behavior of this subtle Power of Nature, and the appearance of new facts has driven the practical telegraphist into lines of inquiry and discovery. Physicists have been metamorphosed into practical engineers, while no telegraph engineer deserves that title unless he also possesses that as a scientific man.

These conclusions are very strongly illustrated by the improvements made in the quality of the conductors employed for the transmission of electric currents.

Copper.—In the first telegraphs of 1837 nothing but copper wire, owing to its high position as a conductor, was used in England, and it was buried underground; but the difficulty then experienced in insulating buried wires was so great, that they were removed from underground and suspended on poles.* The ductility, the want of tensile strength, and the absence of elasticity of copper, as then produced, rendered it impracticable for this purpose. It was speedily replaced by iron. Iron has since been almost universally used for aerial lines, while copper remains the sole material for underground and submarine purposes where mechanical strength is of little consequence. Mechanical strength and price seem to have been the only considerations that governed the choice of conductors in the earlier days; but as soon as speed of transmission assumed a commercial aspect, as it did in 1858, when Atlantic telegraphy was an accomplished fact,

* In 1848 a copper wire was put up between Paris and Rouen.

then the electrical qualities of the material engaged the attention of the telegraph engineer. Sir William Thomson in 1856 pointed out the great differences in conductivity observable in various samples submitted to him, although these samples were supposed to be of the very best quality; while the late Mr. Augustus Matthiessen in 1860 made an exhaustive inquiry into these variations and their causes. He determined the electrical conductivity of pure copper, and defined a standard which is that now in use,† and showed that the variations were due to impurities, principally oxygen and metalloids. A mere trace of arsenic reduced the conductivity 40 per cent., while contact with air when in a molten state reduced it 24 per cent.

The result of Matthiessen's inquiries has been not only to remove the great variations in the conductivity of the copper, but to immensely improve its quality. While in 1861 electricians were content to specify that the copper should not fall below 85 per cent. of pure copper, they now specify 96 per cent, and they obtain it of a remarkable uniform quality. The value of this improvement may be estimated from the fact, that the carrying capacity of a cable for messages is increased in the same proportion as the conductivity of the copper is improved. Thus a cable made of the copper of to-day will carry twice the number of messages that a similar cable of copper would in 1858.

The progressive improvement is shown by the following table:

Cable.	Year.	Conductivity.
Dover and Calais	1851	42.00
Portpatrick and Donaghadee	1852	46.00
Atlantic Cable	1856	50.00
Red Sea	1857	75.00
Malta and Alexandria	1861	87.00
Persian Gulf	1863	89.14
Atlantic Cables	1865	96.00
Irish Cable	1883	97.90
Pure copper		100.00

It is not, however, alone in cables that an improvement of working has been effected by increasing the conductivity of the copper. It has imported additional efficiency to the apparatus. Greater useful effects are obtained with the same current. In all the practical applications of the current, it has an economical advantage, for it lessens the waste of energy in the circuit in direct proportion to the improvement effected. In an electric-light main a difference of 10 per cent. in the purity of the copper might lead to the waste of several HP. The test for purity is extremely simple. Every text-book, or book of tables, has the resistance of a foot-grain, a meter-gramme, a mile-pound, or a knot-pound,* of pure copper at every degree of ordinary temperatures—call this R_t. Take a piece of the cylindrical conductor to be measured. Let w be its weight, l its length, the

$$\frac{R_t\, l^2}{w} = r_1$$

gives its resistance at the temperature at the point of observation if it be truly cylindrical and the copper be pure; but by actual measurement it will be found to be r_2. Then

$$\frac{r_1}{r_2} = \frac{100}{x}, \text{ or } x = 100 \times \frac{r_2}{r_1}.$$

and x is its percentage of purity.

The resistance of all metals is very much affected by temperature. Mathiessen studied this with great care. He found that within ordinary limits the increase due to higher temperatures was approximately expressed by the formula.

$$R_t = R_0 (1 + a t),$$

where R_0 is the resistance at 0° and R_t the resistance at the temperature t. He ascertained the coefficient a to be for pure copper 0.0038. Thus the resistance is increased 38 per cent. between the freezing and boiling points, and it may therefore be increased 20 per cent. between winter and summer temperatures. Hence it is desirable to determine the efficiency of electric-light leads at the highest temperature to which they will be exposed, to avoid unnecessary and injurious waste of energy.

But copper is not only used for submarine cables and for underground lines; it is also employed for overhead wires through towns and many smoky districts. It is not so readily attacked by

† Mathiessen's standard is 100 inches, weighing 100 grains, giving 0.1516 ohm at 60° Fahrenheit.

	weighing			
* 1 metre	1 gramme	= 0.144	ohm at 0° C.	
1 foot	1 grain	= 0.2064	"	"
1 knot	1 pound	= 1091.22	"	"
1 mile	"	= 842	"	"

the gases in the air as in iron or zinc. For such purposes, however, mechanical strength, which is of little consequence in insulated wires, becomes of essential importance.

Copper wire when in the process of manufacture is always drawn cold, and is said to be "hard-drawn" before it is subjected to the annealing process, after which it is called "soft." Soft copper always gives a higher conductivity than hard-drawn copper, but its tensile strength is reduced. Pure soft copper has a very small breaking strain, probably under 10 tons on the square inch, but hard-drawn copper is now supplied that has a breaking strain of 28 tons on the square inch.

Copper wire has been erected in localities where iron wire is destroyed in a few months, and now, after four years' experience, it appears practically unaltered. The diameter of the wire has not been lessened $\frac{1}{1000}$ inch, and it maintains its original qualities unimpaired. In the neighborhood of chemical, varnish and other works it becomes encrusted with a thick deposit, but beneath this it remains unaffected.

Age alone, as far as experience extends, seems to have no appreciable influence on the quality of unstrained copper. Its conductivity and its ductility remain constant. But when copper wire has been removed from magnet coils, such as the field magnets of a dynamo, it becomes brittle, but curiously enough this seems to occur even when the magnets are out of use. Mr. Sabine has found that silk-covered wire, particularly of the finer sizes, wound upon experimental apparatus, gets in a few years equally brittle, whether the instrument is thrown aside or whether it is continuously at work. Neither paraffin nor electro-gilding checks this brittleness. It is probably an effect due to the strains that the wire experiences when wound on a reel and subject to the incessant variations due to change of temperature.

Mathiessen observed no difference produced by the passage of electric currents. The conductors of the Atlantic cables laid in 1858, 1865 and 1866 are found as perfect now as when they were made. The conductors of all cables seem to remain constant. But Gaston Planté discovered that the continued discharge of great quantities of electricity through fine wires rendered them brittle, and Callaud asserted that lightning conductors were very brittle. If that be so, some result may be anticipated from the employment of currents for electric lighting. At present there has scarcely been sufficient experience to teach much on this point.

It is well known that impure copper and its alloys, particularly brass, become brittle when exposed to atmospheric influences in workshops, but this influence has not been observed in telegraphic conductors.

Wires more than twenty years old, used as battery leads, and constantly subject to the transference of electricity through them, show no signs of deterioration. The experience of telegraph engineers is entirely in favor of the constancy and durability of copper as a conductor.

The size of conductors is governed by strictly theoretical conditions, dependent upon the purposes to which they are applied, and it is controlled by commercial considerations. In telegraphy, speed of working is the criterion; in electric lighting, and in the transmission of power, waste of energy is the criterion. Sir William Thomson has given a law which indicates, that the annual value of the wasted energy must equal the interest on the capital expended in laying down the conductor to give the maximum useful economical result. Any departure from this law, to secure low capital expenditure, means shortsighted policy and non-scientific practice.

Copper is imported into the country either as ore or as regulus, bar or ingot. The purest comes either from Japan, Chili, Australia, or from Lake Superior. Much pure copper is produced by the Swansea method of copper-smelting, especially by the modification of that system known as "best selecting;" but within the last few years very pure copper for electrical purposes has been obtained by improvements in the treatment of the metal in the smelting and refining furnaces, some of which have been so successful that there is no difficulty in getting metal giving an electrical conductivity equal to 99 per cent. of pure copper. Great purity of copper is also arrived at by electro-deposition, of which

there are two methods: the one by depositing the metal from a solution obtained from the ore, the other by using impure copper as the anode in a depositing bath containing a standard solution. Electro-deposited copper has not the same mechanical strength as ordinarily refined copper.

At the Paris Electrical Exhibition of 1881 there was one coil of copper wire 1.3 millimeter in diameter, weighing 181 kilogrammes, and measuring 15 kilometers long.

Iron.—Iron has been hitherto used exclusively for overhead wires. In the first days of gutta-percha, about 1849, iron was employed as the conductor to be coated with the new gum, but its inapplicability for this purpose was speedily discovered. Its abundance, its cheapness, and its admirable mechanical properties have singled it out for practical telegraphic purposes; but its resistance is very high, and materially increases the difficulties of the telegraphic engineer. The great improvements effected in the electrical qualities of copper, directed attention to the same qualities in iron; but although copper has been so vastly improved, the same progress has not been made with iron. Copper refiners have relied more upon the aid of the chemist than iron-ware manufacturers. In fact the improvements made have been forced upon the latter. The process in this case has been more tentative and less scientific. There is still room for progress. Although the author had for many years advocated attention to this point, the Americans were the first to specify conductivity in applying for tenders. They defined a standard which was called the Ohm-mile—that is, it was the weight of a cylindrical wire 1 mile in length, which gave a resistance of one ohm at 60° Fahrenheit. While the first iron wire supplied under this specification gave a mile-ohm* of 5,500 lbs., it is now frequently obtained as low as 4,520 lbs. In the present specification of the Post Office the fixed maximum resistance is equivalent to a mile-ohm of 4,800 lbs.

The amelioration made in the quality of iron wire is illustrated by the following measurements:

	Inch.	Ohms.
1873 Iron wire........	0.171	15.31 per mile.
1883 "	0.171	11.30 "

In the earlier days of the telegraph best puddled iron was used for wire, which, however, was very liable to splits and flaws, and an alteration was made by using piled puddled iron or B B (best-best). This description was again improved by the introduction of "box-piled iron" of puddled and English charcoal, sometimes called extra B B, and by four-sided charcoal-piled iron of English charcoal and puddled, which has been called extra special B B; but the terms B B, &c., have now lost all significance—the commonest description of fencing wire only being known by the term. During the last decade a mild English Bessemer steel has been very largely employed, especially for railway telegraphs, and for staying purposes; but the resistance of most wires of this description is high, averaging about 6,800 lbs. per mile-ohm, this high resistance being mainly due to the high percentage of manganese, which in this description of wire varies from 0.25 to 0.75 per cent. The wire used by the Post Office is Swedish charcoal, with a mile-ohm resistance, as already stated, of about 4,520 lbs. Swedish Bessemer, or a specially prepared low carbon English Bessemer, is used by the Indian Government, with a mile-ohm resistance of about 5,400. Cast-steel wire, with a breaking weight of about 80 tons to the square inch, has been adopted on the Continent for telephone circuits with a mile-ohm resistance of 8,000 lbs. The table will show at a glance the various descriptions of iron and of steel telegraph wire which are now in use, or have been used, the tests being given for 0.171 inch, or 400 lbs. to the mile, that being the standard size in England, and a size very largely employed throughout the world.

It will be noticed by the following table, that while in England, where speed of working is the prime consideration, and length of span may be neglected, electricians are satisfied with a breaking strain of 22 tons on the square inch; in tbe Colonies, where long spans are essential, and speed of working is not so important, the specification is 30 tons on the square inch.

* Mile-ohm is more euphonious than ohm-mile, and is used in preference.—W. H. P.

The following chemical analysis of samples of different wires, with their approximate resistances and tensile strengths when annealed for use as telegraph wire, will be interesting:

ANALYSIS OF SAMPLES OF DIFFERENT WIRE.

No. 1. Swedish Charcoal Iron, very soft and pure.
" 2. Swedish Charcoal Iron, good for P. O. specification.
No. 3. Swedish Charcoal Iron, not suited for P. O. specification.
" 4. Swedish Siemens-Martin Steel, 0.10 carbon.
" 5 Best Puddled Iron.
" 6 Bessemer Steel, special soft quality, 0.15 carbon.
" 7 Bessemer Steel, special hard quality, 0.45 carbon.
" 8 Best Cast Steel.

MECHANICAL AND ELECTRICAL TESTS OF SEVEN DESCRIPTIONS OF IRON TELEGRAPH WIRE.

Four samples of each kind.

Description.	Diameter.	Twists in 6 inches.	Elongation.	Breaking Weight.	Resistance per Mile reduced to 0.171 inch at 60° Fahr.
			Per cent.	lbs.	
1. "B B" puddled iron	174½	16	17½	1,470	14.4200
	176½	13	11½	1,380	13.5592
	165	14	15½	1,436	13.8897
	173½	17½	14	1,182	13.8983
2. "B B" piled iron, all puddled	171	16	17	1,220	14.0582
	164½	9	13	1,316	15.5820
	164½	12	11½	1,238	15.6234
	172½	17½	16½	1,292	14.1640
3. "Extra B B." Box piled of puddled and English charcoal, thus—* E. C. P | P | P | P P | P E. C.	168	11	14½	1,456	15.6191
	174	10½	15	1,538	15.3715
	169½	11½	16	1,398	15.5452
	172	12	14½	1,452	15.3017
4. "Extra special B B." Four-sided charcoal-piled English charcoal, and puddled thus—* E. C. E.C. | P | P | E.C. P | P E. C.	172	15	15	1,420	15.5129
	168½	14	14½	1,412	15.6844
	172	10½	14	1,484	16.3574
	172	15	16	1,478	15.5471
5. English Bessemer (known as homogeneous iron)	171½	20	16	1,634	15.9988
	169	19	13½	2,118	18.5663
	170	19½	17½	1,484	14.6922
	168¾	12	14	2,548	19.1480
6. Swedish Bessemer	173½	21	17	1,392	12.6808
	174½	20½	12	1,380	12.9709
	173½	22	18	1,456	13.6587
	171½	13½	17½	1,318	13.0222
7. Swedish charcoal	171	23	13½	1,191	11.3490
	169½	25	10	1,358	11.3052
	169½	24½	13½	1,194	11.2241
	171¼	27½	13	1,128	11.3133

* E. C.=English charcoal. P=puddled iron.

No. of Samples.	1	2	3	4	5	6	7	8
Carbon	0.090	0.100	0.150	0.100	0.100	0.150	0.440	0.620
Silicon	trace	trace	0.018	trace	0.090	0.018	0.028	0.060
Sulphur	trace	0.022	0.019	0.035	0.030	0.092	0.126	0.074
Phosphorus	0.012	0.045	0.058	0.034	0.218	0.077	0.103	0.051
Manganese	0.060	0.030	0.234	0.324	0.234	0.720	1.296	1.584
Copper	trace	trace	trace	trace	0.015	trace	trace	trace
Iron	99.690	99.700	99.440	99.600	99.110	98.740	98.200	97.410
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Mile-ohm at 60° F.	4,546	4,502	4,820	5,308	5,974	6,163	7,468	8,033

This table shows in a very striking way that the electrical conductivity of iron wire increases with the percentage of pure iron, except where the percentage of manganese is high; an increase in the percentage of manganese augments the electrical resistance considerably more than an increase in the percentage of sulphur or phosphorus.

The durability of iron wire is maintained by galvanizing—a most inappropriate title for a very simple operation. The wire, which is first chemically cleaned by being passed through a bath of hydrochloric acid, is then drawn through a bath of molten zinc, at such a pace as will secure the adhesion of the requisite layer of zinc. The zinc becomes oxidized when exposed to the air, and since zinc-oxide is insoluble in water, the wire is protected with an impervious coating; but when this zinc-oxide is exposed to sulphur acids it becomes converted into zinc sulphate, which is soluble. Hence the zinc is removed, the iron is exposed, and oxidation and destruction rapidly supervene.

When the galvanized wire is to be suspended in smoky districts, it is additionally protected by a braided covering, well tarred. In some countries, galvanizing is not resorted to, but simple oiling with boiled linseed oil is depended upon. Such a wire was erected in 1856 between London and Rugby, but the result was very unsatisfactory. More recently (1881) the experiment has been repeated with a similar result. In this climate galvanization is imperative.

But it is not alone in smoky districts where iron wire decays. It suffers much along the seashore. The salt spray decomposes the zinc oxide into soluble compounds, which are washed away and leave the iron exposed, and this is speedily reduced to mere thin red lines.

Where external decay is not evident, time seems to have no apparent effect on iron wire. Wire that has been erected for forty years seems as strong, as elastic, and as conductive as it was at first. In pure country air its durability seems infinite; but sometimes, especially through fir forests, it is subject to some corroding influence. Bauschinger in 1878 tested iron taken from chain bridges that had been erected in 1827 and in 1852, and found the strength and elasticity unimpaired. Thurston found the same in Philadelphia after forty years' exposure. Thirty-nine years of incessant service in conveying currents for telegraphy have not apparently altered the molecular structure of iron wires in the open country on the London and South Western Railway.

Manufacture.—Swedish charcoal iron being now the only description used by the British Post Office, the author has selected it for describing the manufacture of iron telegraph wire. It is imported either in bloom or in rods (principally in rods.) Each rod is rolled down to about 0.26 inch in diameter, and weighs on the average about 1 cwt.

Iron wires used to be drawn in very short lengths, weighing from 15 to 20 lbs., involving numerous welds, splices, or joints—points of great weakness—but now they can be rolled and drawn into lengths longer than are practically required. Coils 0.171 inch in diameter, weighing 400 lbs. and measuring 1 mile have been exhibited, but 110 lbs. is about the best practical limit for transport and use.

By the mills invented by Mr. George Bedson, of Richard Johnson and Nephews, Manchester, the billets can be rolled in this country without welds into rods weighing upwards of 1 ton in weight; and the author would mention how much

telegraph engineers are indebted for the modern improvements in telegraph wire to the various inventions of this gentleman.

The Swedish iron owes its value not only to its comparative purity, but to the fact that it is smelted and puddled entirely with charcoal. The best qualities are a mixture of various ores, and they are known by various brands, the conditions determining these brands being secrets.

The rods arrive in this country dirty and rusty, and the first operation is to cleanse them. This is done by immersion in a bath of diluted sulphuric acid which thoroughly removes every trace of oxide and dirt. The clean rods are then coated with lime to prevent further oxidation, and well baked to dry off all trace of acid. One end of each rod is next pointed to admit of insertion in the draw-hole, and it is then drawn down by one operation to No. 5 W. G., or 0.212 inch in diameter. The act of drawing the wire considerably modifies its molecular structure. It becomes "short," and before it can be drawn down to a smaller size, it must be well and carefully annealed. It is then again cleaned and coated with lime, and reduced to 0.171 inch in diameter. Since the drawing down has again shortened the texture, it has once more to be annealed, before receiving its final operation of galvanization. After galvanization it is straightened by being drawn through a series of jockey rollers, and wound round two wheels, one of which has a slightly quicker motion than the other. It is finally gauged and tested befsre being stored away for future use.

The author has described the manufacture of 400 lbs. wire which is that principally adopted for telegraphic purposes in England, but the explanation is equally applicable to any other size—the wire after each drawing being annealed.

Testing.—The operation ot testing is a most important one, and requisite not only for the user, but also for the manufacturer. Flaws, impurities, faults, notwithstanding the greatest care, will occur, and they can be detected only by the most rigid examination and tests. Tests are mechanical and electrical. The mechanical tests embrace one for breaking strain, another for elongation, and a third for torsive capacity. For hard steel wire, in place of the torsion test, it is usual to specify that the wire shall bear wrapping round its own diameter and unwrapping again without breaking. In France the torsion test is replaced by another by which the wire is bent at a right angle backwards and forwards four times for wire 4 mm. in diameter. Special machines are constructed for the mechanical tests, the condition to be fulfilled being that for the breaking strain the increasing load or stress shall be applied uniformly, without jerks or jumps, and the elongation machine shall correctly register the actual stretch without the wire slipping. The torsive capacity of the wire is determined by an ink mark which forms a spiral on the wire during torsion, the number of spirals indicating the number of twists taken before breaking. The electrical test is simply that for resistance—$\frac{1}{30}$ of a mile of the wire to be examined is wound round a dry wooden drum; and its electrical resistance is taken in ohms by means of a Wheatstone's bridge. Galvanization is tested by dipping in sulphate of copper, and by bending or rolling round a bar of varying diameter, according to the size of the wire.

Specification.—The perfection to which the manufacture of iron wire has been brought is greatly due to the care bestowed upon the specifications by the authorities of the Post Office and of the India Office. No lesson of experience has been neglected; no point has been left open to doubt. The standard has been gradually raised, until it is now very high. It is fixed, and not subject to those continual changes that are irritating and expensive to the manufacturers, who have in consequence been able to select their materials, and to ascertain by experiment the best methods of treatment to produce the high results required.

It cannot be too strongly urged that specification without rigid inspection is valueless. The manufacturer who for his own reputation, and in obedience to the dictates of his conscience, strictly complies with the requirements of a rigid specification at the expense of his pocket, without the check of a subsequent inspection, may exist in theory, but he is not found in practice. Equally difficult

is it to find the careful and painstaking inspector who, possessing the requisite technical knowledge and experience, will rigidly perform his task, regardless of the blandishments of those whose interests are affected by his blindness or carelessness. Many administrations object to the expense of thorough inspection, and the result is they are the recipients of the rejected material of those who do rigidly inspect. One break in the wire costs far more than its inspection, and one extra ohm per mile affects the earning capacity of the wire in inverse proportion.

It is, however, necessary to remark that the mechanical quality of charcoal iron wire sometimes changes with time—its electrical quality remaining unaffected. The molecules seem to set, and the wire to decome harder. This is shown by a diminution in the number of twists, and by an increase in the tensile strength. Tests repeated at some subsequent period may therefore be deceptive, unless allowance be made for the effect of time. Bessemer or homogeneous iron wire as a rule improves in its mechanical properties by being kept in stock.

Gauge.—The vexed question of gauge as applied to wire has been fought with well-nigh the same energy as that of railway gauges. The result is, that confusion has become more confounded. The various Birmingham wire gauges—as various as the seats of the manufacture of iron—were consolidated into one very useful gauge by the Society of Telegraph Engineers; but the Board of Trade has recently taken up the subject, and has issued another gauge, which has the merit of being authorized, It is fixed and legal, and therefore must be accepted. However, it departs so seriously from all recognized gauges, and ignores so completely the metrical system, which is steadily and surely making its way into commercial use, that the Post Office authorities have decided to abandon a gauge altogether as applied to conductors, and to define size by diameter and weight. Thus, in future, all copper wires will be known by their diameters in "mils,"* or thousandths of an inch, and all iron wires by their weights in lbs. per mile. The following table gives the iron wires generally in use:

* The "mil" is one-thousandth of an inch.

Weight per mile.	Diameter.	
lbs.	inch.	millimetres.
800	0.242	6.0
600	0.209	5.2
400	0.171	4.3
200	0.121	3.0
60	0.066	1.85

Steel wire is used for long spans, or for places where great tensile strength is needed; but it is for the external strengthening of deep-sea cables that steel wire is principally adapted. It was first employed in the Atlantic cable of 1865 for this purpose. It has since been generally used for deep-sea cables. The usual diameter is 0.099 in., and it is specified to bear a breaking strain of 1,400 lbs, which is equivalent to 81 tons on the square inch. Steel wire has been produced giving a much higher tensile strength.

Compound Wire.—A compound wire of steel and copper was introduced in America about 1874. It had a steel core for strength with an envelope of copper to secure conductivity and durability. It has a weight only one third of an iron wire of the same resistance. It has been extensively tried in both hemispheres, but without success. It has been impossible to secure permanent adhesion of the envelope and its core. Moisture has in course of time entered, the steel has corroded away, and this, even though the copper envelope has been deposited electrolytically. Light wires of great strength and of low resistance would be of inestimable value to the telegraph engineer, and the failure of the compound wire has been a source of much regret.

Recently a compound wire has been erected between New York and Chicago, a distance of 1,000 miles, giving only 1.7 ohm-resistance per mile. It has a steel core 0.125 inch in diameter, and is coated with copper electrolytically to a diameter of 0.25 inch; it weighs 700 lbs. per mile. It is very expensive. Hard-drawn copper or silicium bronze of a much lighter character would be equally efficient, at probably one-half the cost.

Bronze Wire.—Phosphor bronze, the hard, mechanical qualities and great resisting powers of which are well known, was introduced for telegraph wire about five years ago. Several lengths were

erected by the Post Office. Two long spans cross the channel that separates the Mumbles Lighthouse from the headland near Swansea. The object in view was to obtain great tensile strength, with a power to resist oxidation, especially active where the wire is exposed to sea spray. This was done in 1879, and now, in November, 1883, not the slightest change is noticeable in the wire. But phosphor bronze, though extensively used, has high electrical resistance; its conductivity is only 20 per cent. that of copper. Moreover, the phosphor bronze originally supplied was irregular in dimensions and brittle in character. It would not bear bends or kinks. Great improvements have recently been introduced to remedy these disadvantages.

Phosphor and silicium bronze derive their names not so much because phosphorus and silicium are mixed with the copper, but because they are used in the preparation of the alloy. Pure bronze is a mixture of copper and tin, and in the refining and mixing process phosphorus and silicium have the property of removing impurities, particularly the oxides, though doubtless some of the flux remains. Phosphorus has a most injurious influence on the electrical resistance of the alloy. Silicium is far superior; hence the silicium bronze is preferable for telegraphic purposes. Its efficiency is very great; in fact, phosphor bronze has disappeared for telegraph wire, and has been replaced by silicium bronze.

The conductivity of silicium bronze can be made nearly equal to that of copper, but its mechanical strength is diminished as its conductivity is increased. Wire whose conductivity equals 90 per cent. of pure copper, gives a tensile strength of 28 tons on the square inch; but when its conductivity is 34 per cent. of pure copper, its strength is 50 tons on the square inch. Its lightness, combined with its mechanical strength, its high conductivity and its indestructibility, render it eminently adapted for telegraphs.

The table below gives the results of some tests made by the Post Office upon different specimens of bronze and copper submitted for trial.

Long telegraphic lines, for which iron wire weighing 400 lbs. per mile is now used, can be made of copper or of bronze wire weighing 100 lbs. per mile, which would give higher electrical efficiency; and over-house lines, for which steel wire is often used, can now be replaced efficiently by wire weighing only 30 lbs. per mile, which would be almost invisible.

Experiments on Different Qualities of Wire.

Diameter. Inch.	Diameter. Mm.	Weight per Mile in Pounds	Elongation Per Cent.		Breaking Weight in Tons per Square Inch.	Twists in 6 inches.		Resistance in Ohms at 60° F. Per Mile.	Resistance in Ohms at 60° F. Per Foot-Grain.	Conductivity. Copper=100.
Silicium-Bronze—										
.080	2 056	102.650	1.5 : 1.0 2.0 : 2.0		27.610	13 : 16	23 : 35	8.6359	0.22258	94.616
.059	1.529	58.651	nil	nil	29.368	21 : 25	27 : 53	15.4370	0.22734	92.637
.044	1 133	32.310	nil	nil	47.406	24 : 25	24 : 26	90.3330	0.73285	22.826
.036	0.936	22.698	nil	nil	50.070	23 : 19	11 : 22	157.3900	1.43750	14.650
.081	2.072	102.170	1.5 : 1.0 1.5 : 1.0		29.022 27.470	47 : 19	16 : 20	8.5009	0.21807	96.571
Copper—										
.081	2.072	106.100	nil	nil	30.322	16		11.3490	0.30235	69.60
.082	2.088	107.630	1.5 : 2.5		29.164	27		9.4400	0.25538	82 50
.0847	2.136	116 400	0.5 : 1		30.306	50		9.2400	0.26995	78.00
.081	2.072	105.310	0.5		28.416	84		8.4100	0.22245	94.60

If such overhead wires were erected upon sightly supports, and with some method there would be an end to the meaningless crusade that is now made in some quarters against aerial lines. These, if constructed judiciously, and under proper control, are far more efficient than underground lines. Corporations and local authorities should control the erection, rather than force administrations to needless expense and to reduced efficiency by putting them underground. Not only do light wires hold less snow and less wind, but they produce less electrical disturbance; they can be rendered noiseless, and they allow existing supports to carry a much greater number of wires. Other bronzes have been tried, but without any evident advantage, either in quality or in price.

German Silver.—German silver is employed generally for rheostats, resistance coils, and other parts of apparatus in which high resistance is required. It consists of:

Copper	4 parts.
Nickel	2 "
Zinc	1 "

The variation in its resistance due to changes of temperature is small. Its coefficient is 0.0004—copper being 0.0038—that is, about ten times less. Its resistance per meter gramme is 1.85 ohm, while copper is 0.144 ohm. The effect of agé on German silver is very marked; it becomes brittle. Mr. Willoughby-Smith has found a similar change with age, even in the case of wire drawn from an alloy of gold and silver.

Conclusion.—It is evident, from what has been said, that the form and character of electrical conductors must vary with the purposes for which they are intended. For submarine cables and for electric light mains, where mechanical strength is not required, and where dimensions are of the utmost consequence, the conductors must be constructed of the purest copper producible, for copper is the best practical material at our command.

On the other hand, aerial lines must not only have great tensile strength, but in these days of high-speed apparatus they must have high conductivity, their dimensions must be such as to ensure low electrostatic capacity, they must expose to wind and snow the least possible surface, and they must be practically indestructible. Iron has hitherto occupied the field, but copper and alloys of copper seem in many instances destined to supplant that metal, and to fulfill all the conditions required in a more efficient way, and at no greater cost per mile.

SOLUTION OF TRIGONOMETRICAL PROBLEMS BY CONTINUED APPROXIMATIONS.

By HORACE ANDREWS, Jr., Assistant, New York State Survey.

Written for Van Nostrand's Engineering Magazine.

In solving trigonometrical problems the results will be more or less precise, depending upon the number of decimals employed, when logarithmic tables are used; or upon the size of the drawing, if the results are deduced graphically.

It is frequently very convenient to obtain approximate values of the quantities desired by means of a roughly-drawn diagram, and then to increase the precision of the results to any desired extent. This method is especially valuable where the direct process of computation is complicated, and where the approximate values can be very readily obtained from a diagram. In the three-point problem, much used for locating soundings and subordinate points of a triangulation, a good example is found of the convenience of the method.

As illustrations, two simple problems of plane trigonometry will be taken.

The principles involved are

1st. The sines of the angles of a plane triangle are proportionate to the opposite sides.

2d. The change in the value of the logarithm of the sine of any angle A for a difference of 1″ is equal to M sin 1″ cot. A, where M is the modulus of the com-

mon system of logarithms; log. M sin $1''=1.32335$, for units of the seventh place of decimals, or M sin $1''=0,$-0000021 05.

3d. Cot. B+cot $C=\dfrac{\sin\ (B+C)}{\sin\ B.\sin C}$.

PROBLEM.—*Given two sides* b *and* c, *and the included angle* A *of a plane triangle, to find the remaining parts* B, C *and* a.

Where the large letters denote the angles and the small letters the opposite sides.

Example.—A=75°24'.09''.206. log. b=4.2965477
log. c=4.4184219

From a rough diagram

	C=62° 45' ''
whence	B=41 50 50.794
A+B+C	=180 00 00

log. b sin A=4.2822976	4.28229	(ac) log. M sin 1''=8.6766
log. b=4.2965477	log. sin B=9.82422	log. sin A=9.9857
log. sin A=9.9857499	approx. log. a=4.45807	log. $\dfrac{1}{\text{M.sin}1''\text{sinA}}$=8.6909
log. c=4 4184219	diff. between two values of log. a 281	log.=4.4487
log. c sin A=4.4041718	4.40417	log. sin B=9.8242
	log. sin C=9.94891	log. sin C=9.9489
	approx. log. a=4.45526	818''=2.9127

The first step is to compute precise values of log b sin A and log c sin A, then, using only five places at present, the values of log. $\dfrac{b\sin\ A}{\sin\ B}$, and log. $\dfrac{c\sin A}{\sin C}$. These two values of log. a differ by 28100 in units of the seventh place of decimals.

By using four-place logarithms the value of log. $\dfrac{1}{\text{M sin } 1''\ \sin\ A}$ is first computed, and then the value of the 1st correction 818'' is obtained. It is evident that in order to secure a closer agreement in the values of log. a, B must be increased by 818'', while C is diminished by the same amount. Making these changes, and using now six places, we have

log. b sin A=4.282297	
B=42° 04 '28''.794..log. sin=9.826138	
approximate log. a=4.456159	8.6909
difference between logs.= 7	log. =1.8451
log. c sin A.=4.404171	log. sin B=9.8261
C=62° 31' 22''.....log. sin=9.948019	log. sin C=9.9480
approximate log. a=4.456152	2''.042 0.3101

The second correction, 2.''042, must be subtracted from C and added to B.

log. b sin A=4.2822976	
B=42° 04' 30''.836 log. sin=9.8261433	
approximate log. a=4.4561543	8.6909
difference between logs. 9	log.=0.9542
log. c sin A=4 4041718	log. sin B=9.8261
C=62° 31' 19''.958 log. sin =9 9480166	log. sin C=9.9480
approximate log. a=4.4561552	0''.263....9.4192

	4.2822976
B=42° 04' 30''.573	9.8261427
log. a	4 4561549
	4.4041718
C=62° 31' 20''.221	9.9480168
log. a	4 4561550

An agreement now is found as close as can be expected, unless more than seven-place tables are employed. The process of computation could be stopped at any point where the resulting values of log. a are thought to be sufficiently close.

The operations described above are of a very simple nature. In practice the computer would make some more convenient arrangement of figures than that

given. The time required for the computation will then be found to be less than by the ordinary methods.

For most purposes the values of B, C and log. a, found at the end of the second trial, where only six places were used, would be precise enough.

To illustrate the advantages of a more concise arrangement the computation is repeated below. Seven-place logarithms are here used after the first correction has been obtained, and only one more correction is then found to be necessary.

B=41°50′50″.794	42°04′28″.794	30″.545
log. a=4.45807	4.456 1590	1549
log. sin B=9.82422	9.826 1386	1427
log. b sin A=4.2822976	4.282 2976	2976
log. b=4.2965477		
log. sin A=9.9857499	A=75° 24′ 09″.206	
log. c=4.4184219		
log. c sin A=4.4041718	4.404 1718	1718
log. sin C=9.94891	9.948 0188	0169
log. a=4.45526	4.456 1530	1549
diff. bet. logs. a=28100	60	
C= 62° 45″	62° 31′ 22″	20″.249

(ac)log.M sin 1″=8.6766	
(ac) log. sin A=0.0143	8.6909
log. sin B=9.8242	9.8261
log. sin C=9.9489	9.9480
log. diff.=4.4487	1.7782
818″=2.9127	0.2432=1″.751

The Three-Point Problem.

At a point P three stations l, c and r are visible; l is the station farthest to the left, c is the center station, and r is the one farthest to the right, as seen from P. The angle lcr and the distances lc and lr are given.

The angles lPc=L and cPr=R are measured, and it is required to compute the remaining angles $clP=x$ and $crP=y$, and the sides Pc, Pl and Pr.

The nomenclature adopted is that generally used in locating buoys, etc., by the three-point problem,

$$\text{Let}\quad \frac{cr}{\sin R}\times\frac{\sin L}{cl}=n, \qquad (1)$$

$$\text{then}\quad n.\sin y=\sin x, \qquad (2)$$

$$\text{and}\quad Pc=\frac{cr}{\sin R}\sin y=\frac{\sin x}{\dfrac{\sin L}{cl}} \qquad (3)$$

After plotting l, c and r, the point P can be graphically located by some of the usual methods, *e.g.*, by laying down the angles L and R on tracing paper, and then placing this over the plotted positions of l, c and r so that the lines drawn pass through these points respectively. The position of P can then be pricked through the paper.

Next measure $clP=x$, approximately, and place $y=lcr-(L+R+x)$. Corrections can then be computed to these approximate values until they are as precise as is desirable, then Pc can be readily obtained, and if necessary Pl and Pr.

Example.—

Given lcr=111°10′54″	log. cl=3.797531
L= 44°09′30″	log. cr=3.862668
R= 49°47′20″	
Measured x= 9°	
whence y= 8°14′04″	
$(x+y)$= 17°14′04″	

The value of $(x+y)$ will remain constant, as whatever correction is given to x will be applied to y with an opposite sign.

From (1) first compute n. thus,

log. cr=3.862668	log. sin L=9 843011
log. sin R=9.882906	log. cl=3 797531
log. $\frac{cr}{\sin R}$=3.979762	log. $\frac{\sin L}{cl}$=6.045480

whence log. n=0.025242.

1st Approximation.

	log. n=0.025242	0 2049
y=8°14′04″.	log. sin=9.155016	9.1550
	9.180258	
x=9°	log. sin=9.194332	9.1943
	14074 log.=	4.1484
	1st cor.=504″..	2.7026

(ac) log. M. sin 1″=9.6766. .in units of the
log. sin $(x+y)$=9.4717 6th place.

$$\log.\frac{1}{\text{M}.\sin 1''\sin(x+y)}=0.2049$$

This value of log. $\dfrac{1}{\text{M}.\ \sin 1''\ \sin (x+y)}$ remains constant throughout the computation, and is used for deducing the 1st, 2d, &c., corrections to the assumed values of x and y.

2D APPROXIMATION.

log. n=0.025242	0.2049
y=8°22′28″.log.sin=9.163286	9.1633
9.188528	
x=8°51′36″.log.sin=9.187579	9.1876
	949 log.=2.9773
2d correction=34.″1.....	1.5331

3D APPROXIMATION.

log. n=0.025242	0.2049
y=8°21′53″.9.log.sin=9.162798	9.1628
9.188040	
x=8°52′10″.1.log.sin=9.188039	9.1880
	1 log.=0.0000
3d correction=0″.04	8.5557

The values of y and x are now sufficiently precise, and from (3) we obtain Pc directly.

$\log. \frac{cr}{\sin R}=3.979762$	$\log. \sin x=9.188039$
$\log. \sin y=9.162798$	$\log. \frac{\sin L}{cl.}=6.045480$
$\log. Pc=3.142560$	$\log. Pc=3.142559$

If Pl and Pr are desired they can be computed from the formulae,

$$Pl=\frac{cl. \sin Pcl}{\sin L} \qquad Pr=\frac{cr. \sin Pcr}{\sin R.}$$

The results obtained are very well checked throughout. If care is taken in computing n no subsequent error need be feared, for the computation of Pc, as made above, will check the work.

EXPERIMENTS ON THE EFFICIENCY OF INCANDESCENT ELECTRIC LAMPS.

BY HORACE B. GALE.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

I.

THESE experiments were made by the writer in April and May, 1883, when a student in Mechanical Engineering at the Massachusetts Institute of Technology, and furnished the material for a thesis, from which what follows is selected for publication.

The object of the tests was to ascertain the efficiency of each of the principal forms of incandescent lamps when run at various candle powers. The efficiency, as the term is here employed, is measured by the number of candle lights produced per horse power of electrical energy expended in the lamps themselves.

As much of the work as possible, including the calibration of the instruments used, was done in the laboratories of the Institute. The other experiments were made at one of the lighting stations of the New England Western Electric Light Company in Boston, as the necessary dynamo power could be more readily obtained there than elsewhere. It should be stated, however, that this company had no part in the experiments, and no knowledge of the results, except what was gained afterwards by inspection of the diagrams presented herewith. The forms of lamp tested were the Maxim, the Edison, and the Bernstein. Measurements of the Swan lamp, which it was intended also to include, had to be omitted on account of the limited time which could be spared for the work.

Before describing the experiments, a few words may be devoted to the

GENERAL PRINCIPLES

which govern the efficiency of an incandescent lamp. Each of the lamps mentioned consists essentially of a filament of carbon inclosed in a glass globe, from which the air has been exhausted; the ends of the filament being joined to two platinum wires, which pass through, and are sealed into the glass. These wires form the connections by means of which a current of electricity is sent through the carbon. The energy which must be expended to force the electricity through

the resisting substance of the filament is transformed into heat, which shows itself by raising the carbon to incandescence.

The heat escapes from the carbon filament in three ways: first, a little is conducted away by the connecting wires; second, a still smaller amount, probably, is transferred to the glass by the rarefied gas left in the globe; third, the remainder, which represents practically the whole energy expended in the lamp, escapes from the carbon by radiation. This radiation consists partly of invisible heat, and partly of light; and it is clear that the most efficient lamp is the one in which the largest part of the radiant energy is in the desirable form of light. In other words, the efficiency of an incandescent lamp depends solely upon the proportion between the quantity of energy which is given off as light, and that which is wasted as invisible heat.

Now the ratio between the quantity of light radiated and the quantity of heat radiated by any solid body, depends upon its temperature. The shape or structure of a body, or the extent of its surface, though influencing the total amount of radiation, cannot affect the proportion of the light and the heat.

By adjusting the strength of the current passing through the carbon of an incandescent lamp, we may heat it as hot as we please. We may raise it to a moderately high temperature without getting any light at all, all the energy expended being wasted in the form of heat; increase the quantity of electricity passing through the filament, and we can bring it to a dull red; again augment the current, and it glows with a feeble yellow light; and now, if the current is made a little stronger, without adding much to the amount of *heat* radiated, the intensity of the *light* becomes enormously increased. The way in which the candle power rises, as the current strength is augmented, may be seen in the following table, based on a series of measurements made upon a Maxim "B lamp," designed to give about nine candle power.

Current strength in amperes.	Candle power.	Increments of current strength.	Increments of candle power.
0.	0.		
0.5	0.	0.5	0.
1.0	(very dull red).	0.5	0.
1.5	3.5	0.5	3.5
2.0	17.0	0.5	13.5
2.5	55.0	0.5	38.0
3.0	120.0	0.5	65.0

The efficiency of a lamp, that is, the return we get in light for a given amount of electrical energy, being greater the higher the degree of incandescence to which the carbon is brought, it follows that by varying the candle power of any incandescent lamp, we may, within certain limits, make its efficiency as high, or as low, as we choose. On the other hand, the hotter the carbon is heated, the sooner it is disintegrated and destroyed. A gradual transfer of particles of carbon takes place from the filament to the inner surface of the glass globe; the latter becomes darkened, the resistance of the carbon is raised, and finally the filament breaks at its weakest point.

It is worth noting in this connection, that in the experiment referred to above, the Maxim lamp was run for about fifteen minutes at more than ten times its normal candle power without apparent injury, a fact which speaks well for the endurance of this form of lamp.

While the *efficiency* of an incandescent lamp is thus a matter of temperature, chiefly, being greater the higher the temperature, its *durability* depends both upon the temperature and upon the form, structure, and density of the carbon, as well as upon the perfection of the vacuum obtained in the globe. The *relative economical importance* of the efficiency and the durability of a lamp will vary, of course, in different circumstances, according as the cost of the power, or the cost of renewing the lamp, is the greater; and if we can discover the law connecting the efficiency, length of life, and candle power of a given form of lamp, we can determine, for each special case, at what candle power the lamps should be run in order to obtain the greatest economy.

DESCRIPTION OF LAMPS.

The peculiarities of the various types of incandescent lamps depend mainly upon differences in the carbon filament.

The carbon of the Maxim lamp is made from paper, cut with a die to a shape somewhat like a letter M with its angles rounded. After carbonization, the fila-

ment is placed in a rarefied atmosphere of hydro-carbon vapor, and heated by the current. The vapor is decomposed, and its carbon is precipitated upon the filament in such a way as to obliterate all inequalities in it.

Three styles of Maxim lamp were used in these experiments, rated respectively as 12, 24, and 16 candle power. They were obtained at the Stanhope Street electric light station in Boston, and were taken at random by the writer from a large stock on hand at that place.

The carbon of the Edison lamp is a long, fine filament, made from Japanese bamboo wood, cut to the requisite size in a gauge, and bent into the shape of a U. Three varieties of Edison lamps were experimented upon, rated as 8, 10, and 16 candle power. These lamps were sent from the factory of the Edison Company at Newark.

The Bernstein lamps used in these tests were peculiar in many respects, perhaps the most striking peculiarity being their very low resistance. The carbon consisted of a straight hollow tube, about an inch and a quarter long, of the size of a straw, and terminated by two knobs or bulbs of carbon about a quarter of an inch in diameter, into which the ends of the connecting wires entered. These lamps were obtained by the writer from the factory in Boston. They were rated at 30 candle power. As they had scarcely passed their experimental stage, and have since been improved, the results obtained from them are not presented here as fully as are those obtained from the Edison and Maxim lamps.

RESISTANCE COLD.

The following table shows the resistance of the various lamps when cold. The numbers here given were marked on the bases of the individual lamps to indentify them. The resistances were measured with a large new Wheatstone's bridge made by Williams of Boston, which was used as a standard of resistances throughout the work. Before using it, the coils were tested by comparison with those in the Physical Laboratory at Harvard College. The galvanometer used in the bridge was a Thomson double coil reflecting instrument of 5,000 ohms resistance, made by Elliott Brothers, London. It was mounted on a pier of masonry, and furnished with a compensating magnet and shunt coils, so that it could be made as sensitive as desired.

RESISTANCE OF EDISON LAMPS, COLD.
(Temperature of room, 68°).

10 candle lamps.	8 candle lamps.	16 candle lamps.
Ohms.	Ohms.	Ohms.
No. 21, 380.0	No. 16, 125.0	No. 11, 300.0
" 22, 377.5	" 17, 111.0	" 12, 300.0
" 23, ——	" 18, 114.0	" 13, 291.0
" 24, 384.0	" 19, 107.0	" 14, 268.0
" 25, 396.8	" 20, 108.5	" 15, 297.5
Average, 384.58	Average, 113.10	Average, 291.30

RESISTANCE OF MAXIM LAMPS, COLD.

24 candle (A) lamps.	B-lamps. ("half-lamps.")	16 candle lamps.
Ohms.	Ohms.	Ohms.
No. 1, 75 0	No. 30, 34.0	No. 41, 148.3
" 2, 74.6	" 31, 32.2	" 42, 149.2
" 3, 74.4	" 32, 34.7	" 43, 148.3
" 4, 76.0	" 33, 35.0	" 44, 150.0
" 5, 75.4	" 34, 34.3	" 45, 153.4
Average, 75.08	Average, 34.04	Average, 149.84

RESISTANCE OF BERNSTEIN LAMPS, COLD.

30 candle lamps.

No. 1................	4.37 Ohms.
" 2................	6.47 "
" 3................	1.83 "
" 4................	1.42 "
" 5................	—
Average............	3.52 "

THE PHOTOMETER.

The measurements of candle power were made upon a photometer of the ordinary Bunsen type, having a bar 100 inches long. The disk was inclosed in a box about a foot long, having an opening in each end to admit light, and two mirrors so arranged that both sides of the disk could be viewed at once from an opening in front. The box carrying the disk could be rolled on wheels along a horizontal track, and a pointer projecting downward opposite the disk indicated on a graduated scale the ratio of the intensities of the two lights at the two ends

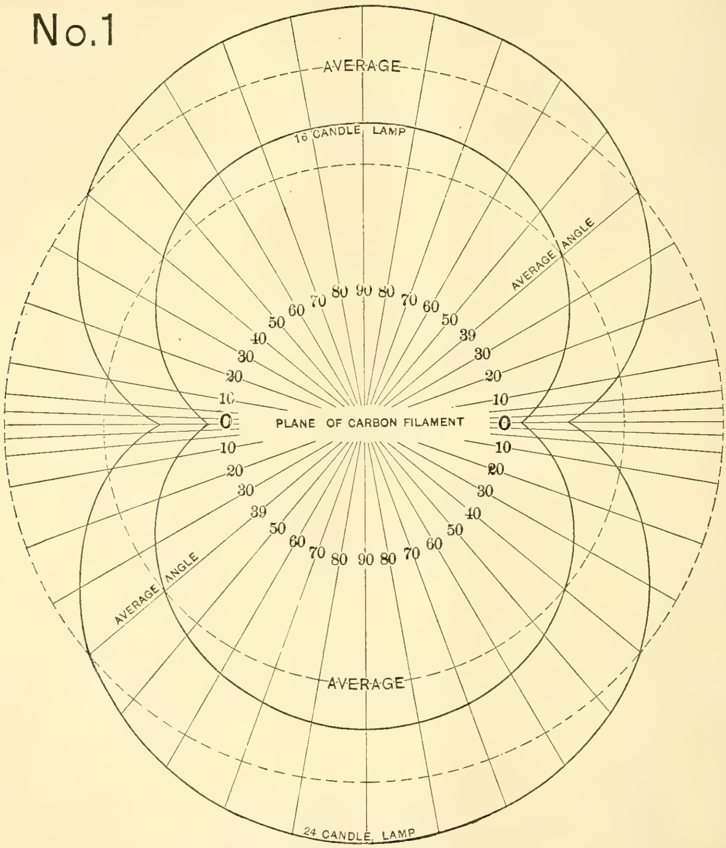
of the bar. The whole was placed in a dark room, the interior of the room, and also the apparatus itself, being painted a dull black.

ILLUMINATION AT DIFFERENT ANGLES.

On account of the shape of the carbon filament, incandescent lamps generally give more light in certain directions than in others; and it is important to know exactly what the variation is, so that we may calculate, from a single measurement of the intensity of the light in a given direction, what is the true average candle power of the lamp. This point was accordingly investigated for each one of the lamps. The method used was to place two lamps of the same kind, connected either in series or in multiple arc, at opposite ends of the photometer bar, and send a current from the same source through both. One of the lamps was then turned about its vertical axis through ten degrees, or less, at a time, as indicated on a graduated circle, and the intensity of the light given off at each angle was compared with that of the other lamp, which remained fixed, and served as a standard.

The principal advantage of this method is, that if any accidental variation in the current should cause the candle power of the lamp tested to vary slightly from its normal value, the brightness of the standard lamp will vary in the same way, so that the ratio of the candle powers will not be affected. It was found that in this way these experiments could be carried on equally well with a current of variable intensity as with a steady current. In all the tests here described, however, the current was kept perfectly steady, by a method which will be described further on.

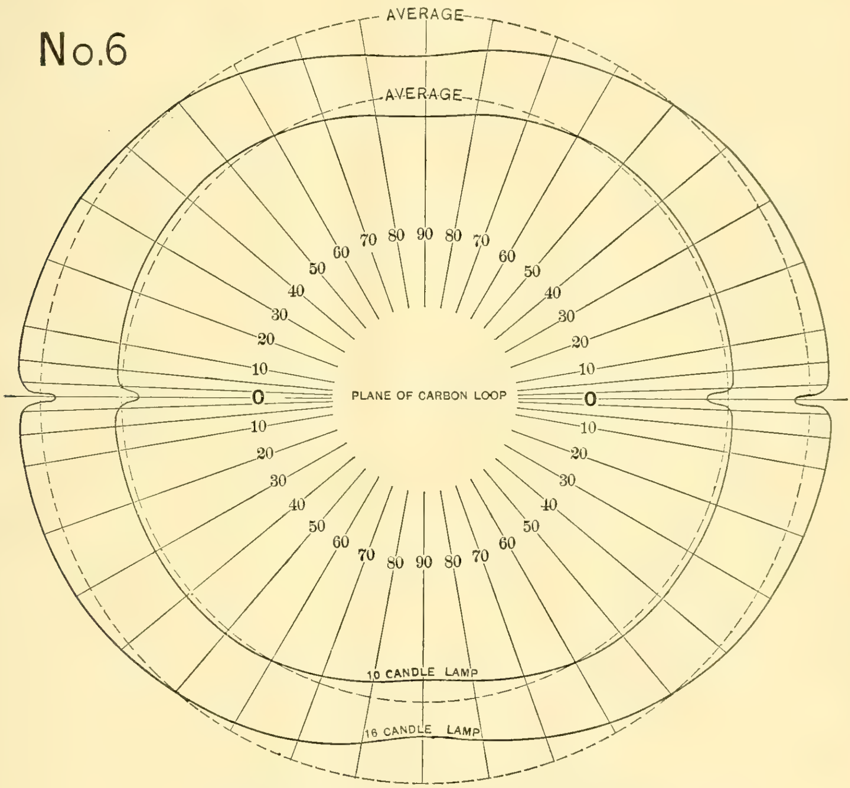
No.1



CURVES OF EQUAL ILLUMINATION. (IN HORIZONTAL PLANE.)

The values of the illumination of each lamp at the different angles were laid off graphically from a center, and a curve drawn through the points thus found. The area of each curve was then measured with a planimeter, and the ratio of the true candle power to the candle power as measured on the face of the carbon loop (*i. e.*, perpendicularly to its plane) was computed for each lamp. curve represents the illumination of the old style, or 24 candle-power, Maxim lamp; and the inner curve that of the Maxim lamp as improved by Mr. Weston, which is the style at present made by the United States Electric Lighting Company, and rated at 16 average candle power. The curves are drawn so that if one imagines the lamp placed in the center, the plane of the carbon filament

No.6



CURVES OF EQUAL ILLUMINATION.(IN HORIZONTAL PLANE.)

The average results for each class of lamps were also plotted in the same way. The forms of the curves obtained, for the Maxim and Edison lamps, are shown by diagrams No. 1 and No. 6.

The photometric measurements were made only in a horizontal plane, because that is the usual method of measuring candle power, though perhaps a fairer comparison of the different lamps would be arrived at by taking the average spherical illumination.

Referring to diagram No 1, the outer being represented by the line 0-0, all points on the curve will be equally illuminated. The carbon of the Maxim lamp, being made from paper, is several times as broad as it is thick; hence we see that the illumination opposite the face, or flat, of the carbon is considerably greater than that on the edge. The variation in brilliancy, as we go from the edge (marked 0) round to the face, is extremely regular for the Maxim lamps, the curves of the individual lamps being almost identical.

Diagram No. 6 shows the same thing for the Edison lamps. Here the carbon filament has its greatest breadth in the direction perpendicular to the plane of the loop, so that the illumination is feeblest on the face, and increases as we go toward the edge. Just in the plane of the loop, however, there is a sudden falling off in the intensity of the light; because when the two arms of the U are exactly in line, one cuts off the light of the other. Though these curves, each showing the average of five lamps, are tolerably regular, the curves for the indvidual Edison lamps are quite irregular, owing to the carbon being more or less twisted.

The illumination of the Swan lamp, one of which was tested at this time, was found to be the most uniform, being practically the same in all directions. It is claimed, however, that a uniform illumination is not always an advantage, as it is often desirable to be able to throw more light in certain directions than in others.

In each of the diagrams a circle is drawn, whose area is equal to the area of the irregular figure bounded by the curve of equal illumination, and the intersection of the circle with that curve gives us the angle at which we should measure the light of the lamp in order to get its true average candle power. A better way, however, and that here adopted, is to measure the candle power of each lamp on the face, and compute its average candle power by referring to the curve for that individual lamp.

SOURCE OF CURRENT.

For experimenting upon incandescent lamps, it is desirable to be able to maintain, for any length of time, a perfectly uniform and steady current of electricity. The available sources of current were in this case a Weston fifteen arc light dynamo machine, having the field in derived circuit, and a Kabath secondary battery of seventy-two cells. The current of the dynamo machine, though tolerably steady, was not perfectly so, on account of slight variations in the speed; and that from the storage batteries, though not subject to fluctuations, would nevertheless run down gradually as the cells became discharged. By using the machine and the battery in combination, however, it was found possible to maintain a current of a perfectly uniform intensity for any desired time. The batteries were connected in series, so that any number of them might be placed in the circuit of the dynamo machine, in derivation with the loop supplying the lamps. The current passing through the lamps could be regulated by means of an adjustable resistance, or by varying the number of cells of the battery in circuit; and a variable resistance was also interposed in the field circuit of the dynamo, so that its electromotive force could be adjusted to just balance that of the battery. The dynamo thus supplied the current to the lamps without exhausting the battery, which merely served to keep the electromotive force on the lamps constant, and absorb any fluctuations that might exist in the current of the dynamo. When the lamps were turned off, the dynamo merely supplied the loss due to leakage and local action in the cells. This arrangement of balanced electromotive forces is, of course, not possible with a dynamo having the field coils in direct circuit.

THE MEASUREMENTS OF CURRENT

were made by means of one of Ayrton and Perry's ammeters, which was carefully calibrated at intervals during the progress of the tests by comparison with a tangent galvanometer. The constant of this galvanometer was computed from the number and diameter of the coils, and the value of the horizontal component of the earth's magnetism as determined at Cambridge, and was also ascertained directly by the electrolysis of a solution of pure sulphate of copper. The results of the two methods were found to differ by less than one per cent.

DETERMINATION OF GALVANOMETER CONSTANT.

In the determination by the deposition of copper, three large Daniell's cells, whose joint resistance in parallel circuit was about .08 of an ohm, were used as a source of current; the circuit was completed through the galvanometer, a resistance box, and a depositing cell with a copper anode and a platinum cathode, the liquid being a saturated solution of chemically pure sulphate of copper. The resistance was first adjusted to obtain a

deflection of the galvanometer needle of a little more than 30°. The platinum cathode was then removed from the cell, washed with distilled water and alcohol, dried, and weighed. The circuit was again closed by lowering the cathode into the solution, and the deflection of the galvanometer was kept constant for about an hour and a half, when the circuit was broken by taking out the cathode, which was washed, dried, and weighed, as before. The data for calculating the galvanometer constant were as follows:

Increase in weight of the cathode . 0 . 22208 gram.
Time during which the current passed......................5095. seconds.
Deflection of galvanometer .....34.675 degrees
Tangent of deflection............0.6918.

Assuming that one ampere of current deposits .00033 gram of copper per second, as given by Prof. S. P. Thompson in his "Electricity and Magnetism," we have,

$$C=\frac{0.22208}{5095.\times.00033}=0.132 \text{ ampere.}$$

Hence the galvanometer constant

$$=\frac{0.132}{.6918}=0.19.$$

The galvanometer had 36 coils, whose mean diameter was 52 centimeters. Computing from these data the value of the horizontal component of the earth's magnetism, we obtain $H=0.165$. The value of H, as determined at Cambridge in 1882, was 0.164.

CALIBRATION OF AMMETER.

To calibrate the ammeter, it was put in circuit with the Daniell's battery, a resistance box, and the galvanometer, the current being divided between the latter and a shunt of No. 12 copper wire. The multiplying power of this shunt was 13.29. By adjusting the resistance the reading of the ammeter was varied by one degree at a time from 0° to 22°, deflections being taken both to the right and left, and simultaneous readings made of the galvanometer. The deflection of the ammeter was found to be proportional to the current, as far as the test could be carried, after making correction for a permanent displacement of the zero point of 0.14°, which was allowed for in all the subsequent work. The ammeter was again calibrated near the middle, and again at the close of the experiments, the results agreeing with the first calibration; thus showing that the strength of the permanent magnet had not altered perceptibly while the work was in progress.

SECOND SERIES OF TESTS.

The object of the next series of observations was to obtain the data from which curves could be constructed for each lamp, showing the variation in candle-power and current strength as the electromotive force is increased. The method consisted in varying the candle power of each lamp by a succession of steps, from zero to as high a point as it could safely be carried, and taking simultaneous measurements of the electromotive force, current, and candle power at every point.

DETERMINATION OF ELECTROMOTIVE FORCE.

The current passing through the lamp could be ascertained directly by means of the ammeter; but the resistance of the lamp when hot being unknown, to find the electromotive force it was necessary to place the lamp in derivation with a coil of wire of known resistance, and measure at the same time the current passing through this coil. The electromotive force was then found by multiplying together the values of the current and resistance.

LONGITUDE BY TELEGRAPH.—The difference of longitude between Buenos Ayres and Valparaiso has been determined by telegraph by M. Beuf, Director of the Naval School of the Argentine Republic; so also has the difference between Valparaiso and Panama, between Valparaiso, Callao and Lima, between Santiago and Valparaiso, and between Santiago and Cerro-Negro. Various French naval officers have undertaken these last determinations. A full account of the operations, by means of the various submarine cables and telegraph wires connecting these places, has been communicated to the French Academy of Science by M. de Bernardieres, Naval Lieutenant, who, in conjunction with M. Beuf, made the Buenos Ayres to Valparaiso, that is to say, the main Transcontinental determination. The result shows that the difference of longitude between the flagstaff of the Bourse of Valparaiso and the Cupola of the Custom House at Buenos Ayres is 63 min. 4.230 sec. The longitude of the flagstaff of Valparaiso Bourse is 4 h. 55 min. 45.11 sec. The latitude of the same spot is given as 33 h. 2 min. 10.1 sec. The latitude of Buenos Ayres (the cupola of the Custom House) is given as 34 h. 36 min. 27.7 sec. The Americans previously measured it by Talcott's method, and found it 34 h. 36 min. 29.8 sec.

THE BEHAVIOR OF ARMOR OF DIFFERENT KINDS UNDER FIRE.

By CAPTAIN ORDE BROWNE, R. A.

From "Iron."

The object of this paper is to notice briefly the features in recent experiments which bring out the characteristic behavior of the principal kinds of armor under the impact of shot, and then to point out the necessity for recognizing that the mechanical conditions of one case may be so entirely different from those of another as to call for different qualities in the shot, and a totally different system of calculating effects. The importance of this question will be apparent if it is borne in mind that there are four principal kinds of armor employed by European powers. The natural tendency is for us to test our own shot and armor against one another. The important matter, however, is to know the behavior of our shot against the particular kind of armor that our enemy may have, not against our own. It appears, perhaps, like killing two birds with one stone if we prove our shot against our own armor. The advantage of such an achievement, however, is lost if one bird is a wrong one, and this may in a certain measure be the case if we continually follow the above course in the face of the adoption of the armor by foreign powers differing widely from our own in its nature. The four kinds of armor to which I refer are as follows:—

1. Wrought iron.
2. Wrought iron with a steel face (termed compound armor).
3. Solid steel; and,
4. Chilled cast iron.

I will first specify, as far as I am able, the characteristic behavior of each under impact, in order that, when I come to them, you may see how far the experiments I notice bear out what is said; and I would observe that these experiments are simply the most important recent ones, and cannot be said to be specially selected.

1. Wrought iron yields locally; it is punched or perforated, a clean hole being made in it. The rest of the target hardly suffers appreciably, except close to the point of impact. The entire shield, including bolts, is generally capable of resisting any subsequent blow as stoutly as it resisted the first one. Effect here must be obviously produced by the bare power of perforation of each round taken singly. Partial perforation is practically useless, however often it may be repeated. The shot experiences but little resistance as its point enters, and hence it is well enclosed and supported round its head before the full strain comes on it. Hardness and rigidity of metal in the projectile here tell to the greatest extent, and tenacity to the least. Need I add that these conditions have favored the use of Palliser's chilled iron shot with sharp points? The plate yields at the back opposite to the point of impact by tearing in a cross or star line, letting the point of the shot through the center.

2. Steel-faced wrought iron (Cammell's, made on Wilson's patent; or Brown's, on Ellis's patent).—Here the steel face which constitutes about one-third of the thickness of the plate, is a harder class of steel than is generally supposed,* and resists the point of the shot abruptly, and severly tries the tenacity of its metal. It is seldom, indeed, that a projectile holds together under these conditions; there is a mechanical force acting something like the outward thrust on the sides of an arch, and the shot sets up, or more commonly breaks to pieces, leaving but little metal lodged in the plate. The plate yields mainly by cracking in radiating lines from the point of impact. In plates badly backed the plate bends slightly back, and very rigid shot occasionally get their points through; but when well backed, the entire plate must be broken in pieces and displaced before a shot gets past it in any

* At Spezia in 1882 the steel faces of Brown's and Cammell's plates contained respectively 0.65 and 0.7 per cent., and Schneider's solid steel plate about 0.45 per cent. of carbon.

sense. In addition to the radial cranks, concentric ones are apt to be developed, sometimes, I think, owing to the tendency of the plate to give back about the point of impact.* Obviously, here tenacity in the shot is called for in a much greater degree than with wrought iron.

3. Solid steel, as made by Schneider and used in many foreign ships, though rather less hard than the steel face of compound plates, is as a mass more rigid. It admits the points of the shot at first with rather less resistance, but it does not yield at the point of impact even when badly backed, and is, therefore, less dependent on backing than compound armor. As the shot enters, it wedges and heaps up the metal round it, the plate coming forward and swelling at the point of impact and yielding by radiating cracks. I have never known of a concentric crack being made in steel armor, nor of the point of the shot getting through until the plate was stripped off. Any cracks made are, I think, much more certain to extend through the metal than in the case of compound plates where face-cracks may be formed, leaving the iron foundation-plate intact.

4. Chilled iron made by Gruson, and used almost universally in foreign coast-armored defences, is very rigid, indeed. The shot never, I believe, gets its point even a single inch into the metal. The shield transmits the shock through its mass, and must be broken up bodily. Chilled iron is used in large masses, and is best suited to resist single blows, especially in an oblique direction. Under the direct blows of heavy shot of high tenacity chilled iron breaks up. Cracks radiating from the point of impact are formed, and the whole shield breaks across. The primary requirement in the shot appears to be tenacity, to enable it to deliver its work on the point of impact before it breaks up, which it does, leaving little or no metal lodged in the shield.

The first experiments to notice are two carried out by Krupp at Meppen, in March, 1882. The targets were examples of remarkably successful perforation of wrought iron by steel projectiles. In one case a 5.9-inch projectile, striking directly, passed easily through two 7-inch iron plates with 10 inches of wood between, and in the other, striking obliquely at 55°, a similar projectile perforated 7.9 inches of iron, with 9.84 inches of wood and 0.98 inches of iron skin. In the first experiment, which was repeated, both projectiles passsed uninjured up the range. In the second, which was also repeated, both the projectiles broke up. I call your attention to the local character of the injury effected on the wrought iron, and the completeness of the perforation, especially when the shot strikes directly.

Next come the Spezia trials of November, 1882, where steel-faced plates 19 inches thick, supplied by Cammell and Brown, competed with 19-inch solid steel supplied by Schneider. Each plate first received a blow from a chilled Gregorini iron projectile weighing 2,000 lbs., fired from a 100-ton gun with sufficient velocity to perforate a wrought-iron plate of 19 inches, that is, about 1,225 feet per second ; secondly, a blow from a similar projectile was delivered on each plate, with a velocity of about 1,560 feet, capable of perforating about 25 inches of wrought iron. The steel-faced plates became wholly or nearly detached, and fell from the backing on the second blow. The steel remained up, and received two more blows from steel projectiles.

At the same time was commenced a very similar trial at Ochta, near St. Petersburg, where 12-inch Cammell steel-faced and Schneider steel plates were attacked by an 11-inch gun, firing chilled-iron projectiles with the necessary velocity to perforate 16.3 inches of iron in the first round, and subsequently the necessary velocity to perforate about 12 inches.

It may be seen that at Spezia the French steel plate stood best, but at Ochta the advantage was still more decidedly in favor of the compound plate. Schneider's Spezzia plate was tempered, and was held up by twenty bolts, while Cammell

* Major O'Callaghan, R.A., Shoeburyness, has contributed a paper to the R.A. Institution, containing a most interesting investigation as to the behavior of steel in steel-faced plates round the point of impact, with his own explanation, and that of Colonel Inglis, of the phenomena exhibited. The original paper should be read by any one who is interested in the matter. Briefly, it may be said that the steel is driven outwards in directions normal to the head of the shot, setting up and buckling as it goes; while the wrought iron yields beneath it, the effect being to produce the separation of the frustrum of a cone of steel from off the face of the target of irregular curved form, with crater-like depressions. It appeared to me that at Spezia the comparatively soft Gregorini shot-points were moulded into a form originated by this action.

and Brown's had only six bolts each. These makers object to the tempering of the steel, urging that their plates were samples of their supply to the Italia, for which plates could not be tempered, because the plates are curved. This placed the steel-faced plates at a disadvantage, and the Italian officers consider that the yielding character of the backing told against the steel-faced plates, which would be much more rigidly supported on the ship's sine. The fall of the fragments makes the difference between the English and French plates appear greater than it was. There the tendency of the steel-faced plates was to give backwards, and the steel to swell at the point of impact. In the steel-faced plates the fracture is concentric as well as radial.

On August 22, 1883, was commenced a remarkable experiment at Shoeburyness on the resisting power of plates of iron and steel-faced plates fastened on granite. The iron consisted of two 8-inch plates, with 5 inches of wood between, and the steel-faced plate was 12 inches thick. The 80-ton gun was fired at these with a projectile of chilled iron weighing 1,700 lbs., with a velocity of nearly 1,600 feet, capable of perforating 24 inches of wrought iron. The shot cut a clean hole through the iron, breaking up, but penetrating nearly 10 feet into the granite. Against the steel-faced (Cammell's) plate it broke up, the head lodging in the plate, cracking and bending, but not breaking or detaching the plate. This last result is an extraordinary one, the plate, when thus well-supported, having borne a blow capable of perforating 24 inches of iron, and containing about 30,000 foot-tons energy, showing what steel-faced iron is capable of enduring under these conditions. There is hardly a case of eccentric cracking. In the case of the wrought iron there is the usual clean perforation.

Three other experiments on perforation deserve notice. Captain Palliser, with a shot whose calculated perforation is about 7.7 inches, completely perforated a wrought-iron plate 8.73 inches thick on April 5, 1883, with a special pointed steel-jacketed shot of reduced diameter; and what, perhaps, deserves more notice, on June 6, 1882, he perforated completely a 4-inch steel-faced plate with a 13-pounder shot of his special pattern, with a striking velocity of 1,550 feet, and a calculated perforation of 4.6 inches of wrought-iron. He also perforated a 6-inch steel-faced plate with an 80-pounder shot.

In August last, Sir Joseph Whitworth, with a 9-inch gun, 29 calibres long, drove a forged steel shell, weighing 403 lbs., through an 18-inch wrought-iron plate, with a striking velocity of about 1,900 feet. The projectile had a good deal of work left in it, smashing up a very heavy cast-iron supporting plate, and passing through an oak backing and steel skin and many feet of wet sand. The projectile is a most remarkable one. In all these last experiments the work is strictly local, especially deserving notice on this account in the case of the steel-faced 4-inch plate.

Finally, I would mention an experiment of a totally different character, namely, one conducted at Buckau, Magdeburg, by Gruson, on October 22, 1883, when a chilled-iron shield with a maximum thickness of 43 inches, weighing 47½ tons, was attacked by a 12-inch Krupp gun (30.5 c.m.), firing a steel projectile weighing about 980 lbs., with a striking velocity of about 1,460 feet, and having an energy, therefore of about 14,500 foot-tons. After three rounds the shield was cracked or broken across in more than one direction, and a fourth shot began the actual displacement of the fragments. There was nothing here of the nature of penetration, the surface only at the points of impact being chipped off. Considering the destruction as effected by the shock on the mass of metal it may be in a sense measured by the energy per ton of shield; this amounts to 916 foot-tons in the whole three blows.

The steel-faced plate on granite at Shoeburyness weighed about 10½ tons, probably. It received a blow of a shot with 30,000 foot-tons energy, or about 2,857 tons per ton of metal. We must not, of course, compare this with Gruson's shield, because, being backed with granite, the plate only represents a portion of the shield, but it is easy to see that it held together under a vast blow. The work on the Gruson shield was delivered in three blows and distributed. The Gruson shield was broken up; our Shoeburyness one was not, but

there would have been a better chance of completely dividing it if a steel shot had been employed. This would have held better together, and perhaps set up, following the opening parts of the plate, instead of a rigid chilled iron shot shivering directly it began to lose its form. My object, however is not so much to make a comparison of the total resisting power of the different classes of armor as to indicate the shape in which the work has to be done, and the consequent mechanical bearings of the question. I think it will be clear to all present that in the case of wrought iron we have simply to deal with perforation. In the first days of the Plate Committee Sir William Fairbairn suggested an equation for the calculation of this work, which with slight modification, answers very well to the present day. Indeed it happens to require less empirical correction with the present guns firing long projectiles at high velocities than those employed in early days. This equation is simply,

$$\frac{Wv^2}{2g} = \pi D t^2 k,$$

where W equals the weight of shot, D the diameter of shot or hole made, v the striking velocity of the force of gravity, t the thickness of plate perforated, and k a constant to be determined practically. The equation consists in putting the total energy or stored-up work in the shot at the moment of impact equal to the work performed on the plate. The left-hand side is absolutely true, and the right-hand side can be shown to be correct in a measure; the only term that is empirical to the full extent is t^2; but under the most important conditions it happens to be most nearly correct. The formula does not apply to cases of partial penetration; but as partial penetration is useless, it really gives us all we need for wrought iron.

To pass on to other cases, we may now and then, in compound plates, get actual perforation, or we may get an instance when a steel shot sets up and drives a disc out of a compound plate, which action may partake of the nature of perforation. With most compound plates, and all solid steel, however, you will observe that the plates are destroyed by fracture, the shot's point penetrating to an insignificant depth. Here, then, we have only fracture caused by a blow delivered by an ogival-pointed wedge. It differs wholly from perforation; for while in both cases the stored up work or energy is the motive power in perforation, the thickness perforated depends inversely on the size of the hole or diameter of the shot; whereas in destruction by fracture the point only of the shot enters the plate, and its diameter can scarcely enter into the question. We may suppose, when all other conditions are the same, fracture effected on any given plate may be simply proportional to the stored-up work; but this fact is of little use to us, for other conditions will very seldom be the same as that of some known example. We want to be able to calculate for varying dimensions of plate and velocity and weight of shot, and this at present we cannot do. The general method of matching a shot against a steel-faced or steel plate is to give the shot sufficient striking energy to perforate wrought iron of the same thickness, or else of 20 per cent. more thickness than the compound or steel plate attacked. This has been the method followed at Shoeburyness, at Spezia, and at St. Petersburg. In each case, the power of the shot to injure armor, which you observe was destroyed by fracture, was calculated on the basis of perforation. It is easy to show that this a totally false principle. Surely armor ought to be divided into two distinct classes, which we may term "soft" and "hard," the former signifying armor which is perforated, and the latter, armor which refuses to yield in this way, and must be broken up. I have tried to illustrate the difference by means of a "dropping apparatus" or "pile-driving machine," which the director of artillery kindly allowed me to have made in the arsenal. There is a weight into which punches, representing ogival shot of different sizes, can be fixed. It would be wrong to assume that results obtained by such insignificant forces necessarily represent what occurs in firing at armor; but we may illustrate principles thus, if it turns out, as it does, that the results here obtained are nearly in accordance with the formula which is proved to be correct, and is in use for problems in armor-piercing. Indeed, I got the machine made, feeling confident that this would be the case. Wrought

iron is represented by millboard slabs, and hard armor by hard brick. The perforations in the millboard slabs are so like those made in iron plates that a photograph of one might almost be mistaken for the other. The hard brick so far resembles hard armor that the point of the shot-punch enters a very short distance before fracture occurs. To test Fairbairn's equation, $\frac{Wv^2}{2g} = \pi Dt^2k$; as the velocity is here due to a fall, we may substitute WH (weight into height) for the stored-up work $\frac{Wv^2}{2g}$ and write $WH = \pi Dt^2k$.

Nothing can well be more simple than this, and you can see that it is fairly carried out, as you can see the height from which the weight drops. It is easy to take one pair of terms and test how one affects the other, leaving all the other terms constant. Here, to bring out my point, I change the diameter and try its effect on H, the height of fall. If I double the D, obviously if the W is kept unaltered I must double the H. Multiply the D by 4, and I must multiply the H by 4. Thus the $\frac{1}{4}$-inch shot punch at 10 inches fall should perforate the same slab as the $\frac{1}{2}$-inch punch with 20 inches fall, and the inch punch with 40 inches fall. At the lowest heights there is some irregularity, but still this is approximately true; the inch punch, you observe, perforates this slab at 60 inches, and the $\frac{1}{4}$-inch at 18 inches fall, because the latter only requires to make a small hole compared with the former. Observe, then, as to the thickness perforated, the $\frac{1}{4}$-inch punch at 17 inches is absolutely equal to the inch at 60 inches. So much for perforation; now for smashing hard armor. The $\frac{1}{4}$-inch punch breaks the brick slab at 10 inches fall. Now, no one here can suppose that the inch punch with the same weight behind it requires four times the fall. You see it is about equal to it with an equal fall. For perforation, then, the energies required, are in the proportion of nearly four to one; for smashing they are equal. Does not this show what a totally wrong principle is followed at Shoeburyness, at St. Petersburgh, and at Spezia, when the shot is matched against hard armor on the data for perforation? I do not mean that results which are grossly wrong are obtained. I have taken extreme conditions to bring out the error palpably, but this error certainly exists in a degree.* It is much easier, however, to find fault than to suggest a remedy. How can hard armor be dealt with? I have been in the habit, when writing in the *Engineer*, of trying to measure the shock against hard armor by the energy per ton of shield, and only learned recently that Gruson employs the same measure. Nevertheless, while it is of some use as a check on the perforation figure, it is itself just as wrong in theory. It is quite clear that there must be some limit as to the distance of the mass we thus deal with from the point of impact. If I strike a long narrow plate near one end, surely it will snap across. The length is immaterial here, and I shall get nearly the same results with two plates, one double the length and weight of the other, and therefore receiving only half the shock per ton. We must not, then, blindly take the whole weight of each plate as the basis of calculation.

The results of fracture constitute so difficult a problem that it has been said that it has nothing to say to mathematical calculation. This, however, you will, I think, not concede. Surely the line of least resistance must be subject to mechanical laws, however hard to discover. Even steel itself, though we may be tempted to think so, is not really capricious, but is bound to follow certain laws. In this question we have no doubt difficult elements. As to dimensions, we have probably primarily to consider the minimum cross measurement as one line of probable fracture, but you will see that from various causes the plate does not always so yield; bolt-holes and other elements may have their influence. Still, while not a guide as to actual direction, the minimum cross measurement may help as to amount of resistance. On the other hand, an increase in the maximum direction or length of a plate is held rather to facilitate cross fracture just as a long stick is more easily broken than a short one. The actual work of cracking is difficult to investigate. Clearly the

* At Copenhagen, in March, 1883, a 9-inch old type Woolwich gun and a 5¾-inch Krupp were fired together. Their powers of perforation were as 118 and 123, while their total energies were 16,403 and 5,760.

first portion of a crack represents much more work than the completion of it, consequently an increase in width of plate would most probably not give a plate a proportional increase in resisting power. Such a question as this could only be investigated by a very extended series of experiments. I would, however, venture to suggest that much might be done on a very small scale. I understand Mr. Whinfield to say that Sir Joseph Whitworth has found that experiments with bullets represent generally the conditions of similar ones with ordnance. I should think, then, that much might be learned by firing steel bullets against a series of small plates of steel and chilled iron, always keeping all conditions uniform, except those whose relation is the object of investigation; comparisons being made as far as possible with such results of experiments with ordnance as we possess. Be this as it may, is it not obvious that at the present moment all nations are in want of experiments made with a view to determine the conditions of fracture of hard armor under impact?

In England we need trials against the hardest classes of armor, that is, solid steel and chilled iron; otherwise, our success in perforating iron, and even steel-faced armor, may tend to develop hardness in our shot at the expense of the tenacity that is needed for the hardest classes of foreign armor. These two classes—solid steel and chilled iron—we ought to have specially in view, because many of the ships which most concern us carry steel, namely, the *Admiral Duperre* and most French ships, as well as the *Duilio* and *Dandolo*, while nearly all foreign coast forts have chilled iron armor. Chilled iron had been adopted for inland forts as well as coast defences in France, owing to its power to resist chilled shot; but in 1882 steel projectiles were tried against it, and produced such effect that chilled iron was then condemned for inland works, which, it may be observed, are liable to be exposed to more prolonged and systematic fire than coast forts. Should we unfortunately retain our chilled shot after foreign powers adopt steel, the above verdict in France would imply that chilled iron forts are good enough to resist English shot, but not those of other nations. At Meppen, in 1879, chilled shot failed against a chilled iron shield, and had to be replaced by steel projectiles. If it be urged that the attack of armored coast forts is an exceptional and undesirable operation, it must surely be admitted that the weakness here brought out must be exhibited in a measure against other hard structures, and is surely a matter to investigate. Last year a commission was sent over from America to investigate the condition of iron and steel in Europe. It is said that the report speaks unfavorably of English steel. This is to be understood if it refer to our steel projectiles, which seem specially to need encouragement at the present time.

Captain Mackinlay, R.A., referring to a remark of Captain Orde Browne's, said he had brought out in a very clear manner the different behavior of steel or compound armor and of wrought iron alone, when struck by a projectile. With the old system of wrought iron it was easy to tell beforehand what might be effected by a given projectile, striking with a given velocity; but experiments with the modern kind of armor showed that the estimation of probable results beforehand was not an easy matter. Mention had been made of a steel-faced plate at Shoeburyness, the resisting power of which was very good, and from the absence of concentric cracks it would appear that that plate had been only slightly deformed, and had been kept in its place by the rigid backing behind it. Contrasting with this the behavior of the compound plates at Spezia, which broke up, it would appear that where the target itself was able to give way considerably, such a plate would be likely to break up. Therefore no estimation of the probable resisting power of any new plate could be well arrived at without a careful consideration of the backing. The frame holding experimental targets was not generally nearly so rigid as that which would contain it on an actual fortification or on a ship. Coast forts might have an advantage over ships, for the reason that it was easy to give a rigid backing to armor on a fort, where weight was of little account, but it was not so easy in the case of a ship; so that if a plate were struck at some point between the ribs, there would not be so good a result as if it had an even surface of granite behind it. Captain Orde Browne said that the heavier

the plate, the better was it able to resist the blow; and that seemed to be a point worthy of great consideration. With wrought iron it apparently did not matter so much what the size of the plate was; the chief point was its thickness. A large plate of steel appeared to have better resisting powers than a smaller one, because to a considerable extent it was able to distribute the blow throughout the whole of it. A few years ago an experiment was made on the English coast by firing at a ship's turret, which received two blows, nearly enough to penetrate it. The object of the experiment was to determine whether the turret could afterwards be revolved, or whether any besides local damage had been inflicted. That turret revolved freely afterwards. In the case of the *Huascar*, in the war between Chili and Peru, the turret could also be revolved after being penetrated several times by 9-inch projectiles. In compound armor the whole effect of the blow was more taken by the whole mass, and it was a question whether turrets made of that new kind of armor would not jam after they were hit. Attention had recently been drawn to this point in the discussion on Colonel Moncrieff's lecture at the Royal United States Service Institution. With regard to armorplates, there are only two manufactories in England, both being in Sheffield. It would be an advantage, from a national point of view, that other makers should take it up, so that there might be several firms to make a large supply of armor if required to meet sudden demands.

Mr. J. Riley said he had often wondered why the government had not done more with regard to steel projectiles. Some years ago he sent for trial half-a-dozen shot and shell made of steel. The Terre Noire Works made shot and shell largely, and why those should be so much more highly prized than shot made in this country he could not understand. Mr. Henry Davey said that it occurred to him that if they could destroy some of the energy of the shot before it was brought on to the actual armorplate, it would be a point of great importance. If one armorplate was put in front of the other, the shot after passing through the first plate would have so much of its energy spent that it would require a less resisting material behind it.

Mr. Scattergood stated that if Captain Browne had said nothing more than was contained in the last five lines of his paper, he had shown that it was the duty of the manufacturers of iron and steel to do the best they could to retrieve what they appeared to have lost—their good name. Captain Browne had referred to the commission sent from America to investigate the condition of iron and steel in Europe, who had reported, it was said, unfavorably of English steel. He supposed the object of bringing forward the paper was to induce the manufacturers of steel to make better steel than they had hitherto done.

The President thought he ought not to allow the discussion to proceed without remarking that Captain Browne distinctly stated that the steel was found not to be suitable for a special purpose, though no fault was found with the steel as steel. It was for those gentlemen who conducted experiments like those of which Captain Browne had spoken to tell the steel manufacturers of the country what were the precise qualities of steel required for their purposes. Whenever that was done, English manufacturers would, he had no doubt, produce steel to satisfy the requirements of artillerists.

Mr. Nordenfelt believed the reason why English manufacturers had had so little chance of showing what could be done in projectiles, as well as other things, was that they had so little opportunity of trying what they made. In England there was a school of gunnery, with highly intelligent officers, and the colonel there had two assistants. But in France, independently of the land artillery, the marine artillery kept a staff of sixteen officers, who did nothing but experiment with the manufacturers of the steelmakers of that country. It was a matter of money. The treasury here did not like to ask for the money, and the officers who had charge of the Government factories dared not ask for money, for if they did they would be snubbed. He believed that the experts in charge of these matters in this country went almost further than Captain Browne, in admitting the value of steel, and in admitting that in this country steel had been made by manufacturers which had done quite as much, if not more, than the French steel projectiles.

The President said that it was his pleasing duty to record a vote of thanks to Captain Browne for his interesting paper, which opened up many subjects worthy of the consideration of his profession, as also of the iron and steel manufacturers of England. Not only iron and steel manufacturers, but the nation also was much indebted to him for having called attention to the serious question of the nature of the projectile which should be prepared for attacking armor of different descriptions. It would be very desirable that they should be informed what was the specific nature of the steel which the Government would in the first instance be willing to test for the purpose to which he had referred. Nothing was better understood than the production of steel of any degree of tenacity and hardness; all the English manufacturers required was to be told what were the qualities best adapted for the purpose intended, viz., breaking the armor up; because he supposed that penetration of the hard armor-plates now generally adopted here and abroad was out of the question.

Captain Orde Browne said that with regard to what Captain Mackinlay had stated, he wished to make it clear that it was so intolerable to have a hole made in a shield and to get a shell far through it so as to explode in the interior, that he looked upon it as a certainty that armor would always be made hard enough to stop that. The introduction of hard armor was having a greater effect upon shot than people were aware of. Economy caused them to try their own shot against their own armor, and he had told the authorities that they ought not to be content with trying wrought iron and steel-faced armor. With the exception of wrought iron, steel-faced armor was the softest of any, and that was the hardest we have in England. Other countries used steel which was harder, and chilled iron which was harder still. These extremely hard kinds of armor called for a different class of projectile to that which had been used in this country. Chilled shot, which did very well for wrought iron, failed against chilled armor. Krupp, in one experiment, wanted to show that a wrought iron shield was better than one of chilled iron. Gruson, a rival of Krupp, manufactured chilled iron, and Krupp wanted to show that his rival's shield was a bad one. He made his rival's shield and his own, and said he would destroy both by chilled projectiles. But he found that his rival's shield stood so much better than he expected, that he took to steel shot, and then in time he broke it up. It was true that a chilled shot going through soft armor would break up, but it would go on and get through, and its front remained perfectly sharp. A softer shot was inferior in penetration, but was better for very hard armor, because if both shot were abruptly resisted before each shot got the support which it did during penetration, the hard shot would smash to pieces, producing but little effect, and the softer shot would produce more effect, although it also broke up. They were rather running on wrong lines in this country, because they kept on using armor which did not bring out the full value of tenacity in the shot. He had never seen chilled iron or steel fired at in this country except one steel target belonging to Sir Joseph Whitworth. Chilled iron was fired at many years ago, but it was then in a very embryo condition. He thought it was detrimental to this country that they did not try shot against the very hard armor used abroad. Captain Mackinlay had called attention to the experiments made against the *Glatton* turret some years ago, and showed that however much they could perforate a wrought iron turret, it could afterwards be revolved, and now they had got rather smaller bores and higher velocities, the shot would penetrate with less resistance and less contortion. The whole thing was, what was the resistance in the act of going through? It looked as if a wrought iron turret would not be affected because they had shot of greater power of perforation. The shot fired at the *Glatton* turret nearly performed the possible work that could be done for the size of the hole it made, and still the turret worked very well. If they substituted hard armor for soft, the work was distributed through the whole mass, and it was more likely to suffer distortion. He had seen a steel-faced target at Shoeburyness in which the whole plate was driven back several inches, but they never could see a thing like that in wrought iron. That was a serious thing for a turret, because if the shot had sufficient work in

it it might have lifted the entire turret up; and the reason it did not dislocate the turret was, because the work was local and rapid. The *Inflexible* had steel-faced armor, and therefore, as they went on to harden armor, there might come a time when it might be necessary to try further experiments, such as firing at an armor-plated ship. With regard to double plates the question was a very large one, and some very odd effects had been produce by them. One was that if they had two plates, with a space in between, and fired a chilled shot at them, the shot would go through a comparatively insignificant front plate, and then on striking the back plate it would fly into fragments. That could not be utilized, because foreign nations did not use chilled shot, and because they might fire a shell which would blow the front plate off. Supposing they had a steel plate capable of keeping out a certain shot, and they put a thin wrought iron plate in front of it, the shot that was before kept out would now go through the iron, steel, and all, for the reason that it was not resisted when its point only touched the shield. If they resisted the shot when its point only was touching, they got an outward thrust and smashed the shot to pieces; but if the shot were allowed to get its head in, it was then supported all round, and would go through. He had stated that the Americans spoke unfavorably of English steel, but he hoped he was not responsible for everything that Americans said. The report was not out yet, but it had been hinted to him that it stated that English steel was in a bad state. He could only attribute that to the fact that they had not made steel shot on a large scale, for the reason that the government would not have it, and he did not think the government fully appreciated the position of the question. Steel projectiles were expensive, but they had to prove them against targets, and the targets cost money. If any one made a steel projectile, and sent it to Shoeburyness to be tested, he would only have the opportunity of trying it as far as he had money to spend, at the rate of £4,000 or £5,000 for each shield of iron, and he could not try more than two or three shots at each plate. Then if it turned out badly the maker's reputation was staked upon it.

He once tried to persuade the ordnance committee to this. He believed the manufacture of steel shot in the country wanted developing very much indeed. The French a year and a half or two years ago adopted cast chilled iron armor, and retained it as long as they fired chilled shot, but when once they fired steel shot they condemned the whole thing. At this moment all English ships carried chilled iron shot, and not steel. The French chilled iron shields then were good enough to resist our chilled shot, but not steel shot; and a foreign nation that adopted steel shot would have projectiles much better than our own. Anything that could be done to prove the necessity for the manufacture of steel projectiles in this country would, he believed, be of great service, and that was one of his reasons for bringing forward this paper.

The Conductivity of Copper.—The true nature of electrical resistance is by no means well known; and the only light which the induction balance of Professor Hughes has as yet shed upon it has not revealed its true nature. An interesting observation recently made by Mr. W. Groves, the well-known practical electrician of Bolsover Street, W., deserves to be more widely known. Mr. Groves took thin discs of brass and coated them by electro-deposition with a thick layer of pure crystalline copper. He then cut similar discs of copper from the deposit and tested them in the induction balance. The scale gave 200 as their induction value. The same discs, after being melted in a founder's furnace, only gave 100 on the scale, and after a second melting their induction value had fallen to nearly that of ordinary sheet copper, namely from 50 deg. to 80 deg. If, as many believe, the induction value represents the conductivity of the copper, there is here a great falling off, and it might be valuable not only in a theoretical, but a practical sense, to find out the true cause. Dr. Mathiessen found that copper lost in conductivity by absorption of oxygen, and the pure copper being fused in an ordinary founder's furnace may have lost its electric conducting power by absorption of this impurity. Should that prove to be the case there is much to be gained by fusing copper in presence of hydrogen, which, uniting with the oxygen, would form water, and leave the copper in its pure condition. To ascertain this it will be necessary to call in the aid of chemistry, and analyze the copper so treated. Mr. Grove's experiment is interesting as opening up a field for further investigation. Should the effect in question not be traceable to the absorption of oxygen it may be due to the molecular structure of the copper in the three cases mentioned, the crystalline structure of the first case being more conductive than the molten structure in the other two cases.

THE TWO MANNERS OF MOTION OF WATER.*

By Prof. OSBORNE REYNOLDS, F.R.S.

From "Nature."

It has long been a matter of very general regret with those who are interested in natural philosophy that in spite of the most strenuous efforts of the ablest mathematicians the theory of fluid motion fits very ill with the actual behavior of fluids, and this for unexplained reasons. The theory itself appears to be very tolerably complete, and affords the means of calculating the results to be expected in almost every case of fluid motion, but while in many cases the theoretical results agree with those actually obtained, in other cases they are altogether different.

If we take a small body, such as a raindrop, moving through the air, the theory gives us the true law of resistance; but if we take a large body, such as a ship moving through the water, the theoretical law of resistance is altogether out; and what is the most unsatisfactory part of the matter is that the theory affords no clue to the reason why it should apply to the one class more than to the other.

When, seven years ago, I had the honor of lecturing in this room on the then novel subject of vortex motion, I ventured to insist that the reason why such ill success had attended our theoretical efforts was because, owing to the uniform clearness or opacity of water of water and air, we can see nothing of the internal motion, and while exhibiting the phenomena of vortex rings in water, rendered strikingly apparent by partially coloring the water, but otherwise as strikingly invisible, I ventured to predict that the more general application of this method, which I may call the method of color bands, would reveal clues to those mysteries of fluid motion which had baffled philosophy.

To-night I venture to claim what is, at all events, a partial verification of that prediction. The fact that we can see as far into fluids as into solids naturally raises the question why the same success should not have been obtained in the case of theory of fluids as in that of solids. The answer is plain enough. As a rule there is no internal motion in solid bodies, and hence our theory, based on the assumption of relative internal rest, applies to all cases. It is not, however, impossible that, at all events, a seemingly solid body should have internal motion, and a simple experiment will show that if a class of such bodies existed they would apparently have disobeyed the laws of motion.

These two wooden cubes are apparently just alike, each has a string tied to it. Now, if a ball is suspended by a string you all know that it hangs vertically below the point of suspension, or swings like a pendulum; you see this one does so, the other, you see behaves quite differently, turning up sideways. The effect is very striking so long as you do not know the cause. There is a heavy revolving wheel inside, which makes it behave like a top.

Now, what I wish you to see is, that had such bodies been a work of nature, so that we could not see what was going on—if, for instance, apples were of this nature while pears were what they are, the laws of motion would not have been discovered, or, if discovered for pears, would not have applied to apples, and so would hardly have been thought satisfactory.

Such is the case with fluids. Here are two vessels of water which appear exactly similar, even more so than the solids, because you can see right through them, and there is nothing unreasonable in supposing that the same laws of motion would apply to both vessels. The application of the method of color-bands, however, reveals a secret—the water of the one is at rest, while that in the other is in a high state of agitation.

I am speaking of the two manners of motion of water—not because there are only two motions possible; looked at by their general appearance the motions of water are infinite in number; but what it

* Lecture at the Royal Institution, on Friday, March 28.

is my object to make clear to-night is, that all the various phenomena of moving water may be divided into two broadly distinct classes, not according to what with uniform fluids are their apparent motions, but according to what are the internal motions of the fluids which are invisible with clear fluids, but which become visible with color-bands.

The phenomena to be shown will, I hope, have some interest in themselves, but their intrinsic interest is as nothing compared to their philosophical interest. On this, however, I can but slightly touch. I have already pointed out that the problems of fluid motion may be divided into two classes, those in which the theoretical results agree with the experimental and those in which they are altogether different. Now what makes the recognition of the two manners of internal motion of fluids so important is, that all those problems to which the theory fits belong to the one class of internal motions. The point before us to-night is simple enough, and may be well expressed by analogy. Most of us have more or less familiarity with the motion of troops, and we can well understand that there exists a science of military tactics which treats of the best manœuvres to meet particular circumstances. Suppose this science proceeds on the assumption that the discipline of the troops is perfect, and hence takes no account of such moral effects as may be produced by the presence of an enemy. Such a theory would stand in the same relation to the movements of troops as that of hydrodynamics does to the movements of water. For although only disciplined motion may be recognized in military tactics, troops have another manner of motion when anything disturbs their order. And this is precisely how it is with water; it will move in a perfectly direct disciplined manner under some circumstances, while under others it becomes a mass of eddies and cross streams, which may be well likened to a whirling struggling mob, where each individual element is obstructing the others. Nor does the analogy end here. The circumstances which determine whether the motion of troops shall be a march or a scramble are closely analogous to those which determine whether the motion of water shall be direct or sinuous. In both cases there is a certain influence necessary for order: with troops it is discipline, with water it is viscosity or treaclyness. The better the discipline of the troops, or the more treacly the fluid, the less likely is steady motion to be disturbed under any circumstances. On the other hand speed and size are in both cases influences conducive to unsteadiness. The larger the army and the more rapid the evolutions, the greater the chance of disorder; so with fluid, the larger the channel and the greater the velocity the more chance of eddies. With troops some evolutions are much more difficult to effect with steadiness than others, and some evolutions which would be perfectly safe on parade would be sheer madness in the presence of an enemy. It is much the same with water.

One of my chief objects in introducing this analogy is to illustrate the fact that even while executing manœuvres in a steady manner there may be a fundamental difference in the condition of the fluid. This is easily realized in the case of troops, difficult and easy manœuvres may be executed in equally steady manners if all goes well, but the conditions of the moving troops are essentially different, for while in the one case, any slight disarrangement would be easily rectified, in the other it would inevitably lead to a scramble. The source of such a change in the manner of motion may be ascribed either to the delicacy of the manœuvre or to the upsetting disarrangement, but as a matter of fact both these causes are necessary. In the case of extreme delicacy an infinitely small disturbance, such as is always to be counted upon, will effect the change. Under these circumstances we may well describe the condition of the troops in the simple manœuvre as stable, while that in the difficult manœuvre is unstable, *i. e.*, will break down on the smallest disarrangement. The small disarrangement is the immediate cause of the break-down in the same sense as the sound of a voice is sometimes the cause of an avalanche, but since such disarrangement is certain to occur a condition of instability is the real cause of the change.

All this is exactly true for the motion of water. Supposing no disarrangement, the water would move in the manner

indicated in theory, just as if there were no disturbance an egg would stand on its end, but as there is always some slight disturbance it is only when the condition of steady motion is more or less stable that it can exist. In addition then to the theories either of military tactics or of hydrodynamics, it is necessary to know under what circumstances the manœuvres of which they treat are stable or unstable. It is in definitely separating these that the method of color-bands has done good service, which will remove the discredit in which the theory of hydrodynamics has been held.

In the first place it has shown that the property of viscosity or treaclyness possessed more or less by all fluids is the general influence conducive to steadiness, while, on the other hand, space and velocity have the counter influence. Also that the effect of these influences is subject to a perfectly definite law, which is that a particular evolution becomes unstable for a definite value of the viscosity divided by the product of the velocity and space. This law explains a vast number of phenomena which have hitherto appeared paradoxical, one general conclusion is that with sufficiently slow motion all manners of motion are stable.

The effect of viscosity is well shown by introducing a band of colored water across a beaker filled with clear water at rest. Then, when all is quite still, turn the beaker about its axis. The glass turns, but not the water, except that which is quite close to the glass. The colored water which is close to the glass is drawn out into what looks like a long smear, but it is not a smear. It is simply a color-band extending from the point in which the color touched the glass in a spiral manner inwards; showing that the viscosity is slowly communicating the motion of the glass to the water within. To show this it is only necessary to turn the beaker back, and the smear closes up until the color-band assumes its radial position. Throughout this evolution the motion has been quite steady—quite according to the theory.

When water flows steadily, it flows in streams. Water flowing along a pipe is such a stream. This is bounded by the solid surface of the pipe, but if the water is flowing steadily we can imagine the water to be divided by ideal tubes into a faggot of indefinitely small streams, any one of which may be colored without altering its motion, just as one column of infantry may be distinguished from another by color.

If there is internal motion, it is clear that we cannot consider the whole stream bounded by the pipe as a faggot of elementary streams, as the water is continually crossing the pipe from one side to another, any more than we can distinguish the streaks of color in a human stream in the corridor of a theatre.

Solid walls are not necessary to form a stream. The jets from a fountain or cascade in Niagara are streams bounded by free surfaces. A river is a stream half bounded by a solid surface. Streams may be parallel, as in a pipe; converging or diverging, as in conical pipes; or they may be straight and curved. All these circumstances have their influence on stability in the manner indicated in the accompanying diagram:

Circumstances	Conducive to
Direct or Steady Motion	*Sinuous or Unsteady Motion*
(1) Viscosity or fluid friction which continually destroys disturbance. Thus treacle is steadier than water.	(5) Particular variation of velocity across the stream, as when a stream flows through still water.
(2) A free bounding surface.	(6) Solid bounding walls.
(3) Converging solid boundaries.	(7) Diverging solid bounding walls.
(4) Curvature of the streams with the velocity greatest on the outside.	(8) Curvature with the velocity greatest on the inside.

It has for a long time been noticed that a stream of fluid through fluid otherwise at rest is in an unstable condition. It is this instability which renders flames and jets sensitive to the slight disarrangement caused by sound.

I have here a glass vessel of clean water in front of the lantern, so that any color-bands will be projected on to the screen. You see the ends of two vertical tubes facing each other: nothing is flowing through these tubes, and the water in the vessel is at rest. I now open two taps, so as to allow a steady stream of colored water to enter at the lower pipe, water flowing out at the upper. The water enters quite steadily, forms a sort of vortex ring at the end, which proceeds across the vessel, and passes out at the

lower pipe. The colored stream then extends straight across the vessel, and fills both pipes: you see no motion; it looks like a red glass rod. The red water is, however, flowing slowly, so slowly that viscosity is paramount, and hence the stream is steady. As the speed is increased, a certain wriggling, sinuous motion appears in the column; a little faster and the column breaks up into beautiful and well-defined eddies, and spreads into the surrounding water, which, becoming opaque with color, gradually draws a veil over the experiment. The final breaking up of the column was doubtless determined by some slight vibration in the apparatus, but such vibration, which is always going on, will not affect the stream until it is in a sufficiently unstable condition. The same is true of all streams bounded by standing water.

If the motion is sufficiently slow, according to the size of the stream and the viscosity, the stream is steady and stable. Then at a certain critical velocity, determined by the ratio of the viscosity of the water to the diameter of the stream, the stream becomes unstable. So that under any conditions which involve a stream through surrounding water, the motion becomes unstable at sufficiently great velocities.

Now one of the most noticeable facts in experimental hydrodynamics is the difference in the way in which water flows along contracting and expanding channels. Such channels are now projected on the screen, surrounded and filled with clean, still water. The mouth of the tube at which the water enters is wide; the tube then contracts for some way, then expands again gradually until it is as wide as at the mouth. At present nothing is to be seen of what is going on. On coloring one of the elemetary streams, however, outside the mouth, a color-band is formed. This color-band is drawn in with the surrounding water, and shows what is going on. It enters quite steadily, preserving its clear streak-like character until it has reached the neck, where convergence ceases; then on entering the expanding channel it is altogether broken up into eddies. Thus the motion is direct and steady in the contracting tube, sinuous in the expanding.

The theory of hydrodynamics affords no clue to the cause of this difference, and even as seen by the method of color-bands the reason for the sinuous motion is not obvious. If the current be started suddenly at the first instant, the motion is the same in both parts of the channel. Its changing in the expanding pipe seemed to imply that there the motion is unstable. If this were so, it ought to appear from the theory. I am ashamed to think of the time spent in trying to make this out from the theory without any result. I then had recourse to the method of color again, and found that there is an intermediate stage.

When the tap is first opened, the immediately ensuing motion is nearly the same in both parts; but, while that in the contracting tube maintains its character, that in the expanding changes its character: a vortex ring is formed which, moving forwards, leaves the motion behind that of a parallel stream through the surrounding water. When the motion is sufficiently slow, the stream is stable, as already explained; there is then direct motion in both the contracting and expanding portions of the tube, but these are not similar, the first being a faggot of similar elementary contracting streams, the latter being that of one parallel stream through surrounding fluid. The first is a stable form, the second an unstable, and on increasing the velocity the first remains, while the second breaks down, and as before, the expanding tube is filled with eddies. This experiment is typical of a large class of motions. Whenever fluid flows through a narrow neck, as it approaches the neck it is steady, after passing the neck it is sinuous. The same is produced by an obstacle in the middle of a stream, and virtually the same by the motion of a solid through the water.

The object projected on the screen is not unlike a ship. Here the ship is fixed and the water flowing past it, but the effect would be the same were the ship moving through the water. In the front of the ship the stream is steady, so long as it contracts, until it has passed the middle; you then see the eddies formed as the streams expand again round the stern. It is these eddies which account for the difference between the actual and theoretical resistance of ships.

It appears then that the motion in the

expanding channel is sinuous, because the only steady motion is that of a stream through still water. Numerous cases in which the motion is sinuous may be explained in the same way, but not all. If we have a parallel channel, neither contracting or expanding, the steady moving streams will be a faggot of steady parallel elementary streams all in motion but having different velocities, those in the middle moving the fastest. Here we have a stream, but not through standing water. When this investigation began, it was not known whether such a stream was ever steady; but there was a well-known anomaly in the resistance encountered in parallel channels. In rivers and all pipes of sensible size experience had shown that the resistance increased as the square of the velocity, whereas in very small pipes, such as represent the smaller veins in animals, Poiseuille had proved that the resistance increased as the velocity. Thus since the resistance would be as the square of the velocity with sinuous motion, and as the velocity in the case of direct motion, it appeared that the discrepancy would be accounted for if it could be shown that the motion becomes unstable at sufficiently large velocities according to the size of the pipe. This has been done. You see on the screen a pipe with its end open. It is surrounded by water, and by opening a tap I can draw the water through it. This makes no difference to the appearance until I color one of the elementary streams, when you see a beautiful streak of color extend all along the pipe. So far the stream has been running steadily, and it appears quite stable. As the speed increases the color-band naturally becomes finer, but on reaching a certain speed the color-band becomes unsteady and mixes with the surrounding fluid filling the pipe. This sinuous motion comes on at a definite velocity; diminish the velocity ever so little, the band becomes straight and clear, increase it again and it breaks up. This critical speed depends on the size of the tube in the exact inverse ratio, the smaller the tube the greater the velocity. Also the more viscous the fluid the greater the velocity.

We have here, then, not only a complete explanation of the difference in the laws of resistance generally experienced, and that found by Poiseuille, but also we have complete evidence of the instability of steady streams flowing between solid surfaces. The cause of this instabillty is not yet completely ascertained, but this much is certain, that while lateral stiffness in the walls of the tube is unimportant, inextensibility or tangential rigidity is essential to the creation of eddies. I cannot show you this, because the only way in which we can produce the necessary condition is by wind blowing over the surface of water. When the wind blows over water it imparts motion to the surface of the water just as a moving solid surface. Moving in this way the water is not susceptible of eddies, it is unstable, but the result is waves. This is proved by a very old experiment, which has recently attracted considerable notice. If oil be put on the surface it spreads out into an indefinitely thin sheet, with only one of the characteristics of a solid surface, it offers resistance, very slight but still resistance to extension or contraction. This resistance, slight as it is, is sufficient to entirely alter the character of the motion. It renders the motion of the water unstable internally, and instead of waves, what the wind does is to produce eddies beneath the surface. To those who have observed the phenomenon of oil preventing waves there is probably nothing more striking throughout the region of mechanics. A film of oil so thin that we have no means of illustrating its thickness, and which cannot be perceived except by its effects—which possesses no mechanical properties that can be made apparent to our senses—is yet able to prevent an action involving forces the strongest that we can conceive, able to upset our ships and destroy our coasts. This, however, becomes intelligible when we perceive that the action of the oil is not to calm the sea by sheer force, but merely, as by its moral force, to alter the manner of motion produced by the action of the wind from that of the terrible waves on the surface into the harmless eddies below. The wind brings the water into a highly unstable condition, into what morally we should call a condition of great excitement; the oil, by an influence we cannot perceive, directs this excitement. This influence, although insensibly small, is, however, now proved

to be of a mechanical kind, and to me it seems that this instance of one of the most powerful mechanical actions of which the forces of nature are capable of being entirely controlled by a mechanical force, so slight as to be imperceptible, does away with every argument against strictly mechanical sources for what we may call mental and moral forces.

But to return to the instability in parallel channels. This has been the most complete, as well as the most definite result of the method of color-bands. The circumstances are such as render definite experiments possible; these have been made, and reveal a definite law of instability, which law has been tested by reference to all the numerous and important experiments that have been recorded with reference to the law of resistance in pipes, whence it appears that the change in the variation of the resistance from the velocity to the square of the velocity agrees as regards the velocity at which it occurs with the change from stability to instability. It is thus shown that water behaves in exactly the same manner, whether the channel is, as in Poiseulle's experiments, of the size of a hair, or whether it be the size of a water main or of the Mississippi, the only difference being that, in order that the motions may be compared, the velocities must be inversely as the size of the channels. This is not the only point explained.

If we consider other fluids than water, some fluids like oil or treacle apparently flow more slowly and steadily than water; this, however, is only in smaller channels. The velocity at which sinuous motion commences increases with the viscosity. Thus, while water in ordinary streams is always above its critical velocity and the motion sinuous, the motion of treacle in such streams as we see is below its critical velocity and the motion is steady. But if nature had produced rivers of treacle the size of the Thames, the treacle would have flowed as easily as water. Thus, in the lava streams from a volcano, although looked at closely the lava has the consistency of a pudding, in the large and rapid streams down the mountain side the lava flows with eddies like water.

There is now only one experiment left. This relates to the effect of curvature in the streams on the stability of the motion. Here again we see the whole effect altered by apparently a very slight cause. If the water be flowing in a bent channel in steady streams, the question as to whether the motion will be stable or not turns on the variation of the velocity across the channel. In front of the lantern is a cylinder with glass ends, so that the light passes through in the direction of the axis. The cylinder is full of water, the disk of light on the screen being the light which passes through this water, and is bounded by the circular walls of the cylinder. By means of two tubes temporarily attached, a stream of color is introduced so as to form a color-band right across the cylinder, extending from wall to wall; the motion is very slow, and, the taps being closed and the tubes removed, the color-band is practically stationary. The vessel is now caused to revolve about its axis. At first only the walls of the cylinder move, but the color-band shows that the water gradually takes up the motion, the streak being wound off at the ends into two spiral lines, but otherwise remaining still and vertical: when the streak is all wound off and the spirals meet in the middle, the whole water is in motion. But as the vessel is still revolving, the motion is greatest at the outside, and is thus stable. There are no eddies, although the spiral rings are so close as nearly to touch each other. The vessel stops, and gradually stops the water, beginning at the outside. If this went on steadily, the spirals would be unwound and the streak restored; but as the velocity is now greater towards the center, the motion is unstable for some distance from the outside, and eddies form, breaking up the spirals for a certain distance towards the middle, but leaving the middle revolving steadily. Besides indicating the effect of curvature, this experiment neatly illustrates the action of the earth's surface on the air moving over it, the variation of temperature having much the same effect on the stability of the moving fluid as the curvature of the vessel. The moving air is unstable for a few thousand feet above the earth's surface, and the motion consequently sinuous to this height. The mixing of the lower and upper strata produces the heavy cumulus clouds, but above this the influence of the tempera-

ture predominates; the motion is stable, and clouds, if they form, are stratus, like the inner spirals of the color-bands.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS, May 21, 1884. Vice-President Wm. H. Pane in the chair, John Bogart, Secretary.

A description of a permanent transmitting dynamometer, constructed by the late Prof. Charles A. Smith, M. Am. Soc. C. E., was read. This dynamometer was put up in connection with the machine and engine rooms of the ManualT raining School at St. Louis, and has been in coustant use for seven years. Its peculiarity is simplicity. The tension of a belt being measured through a balance beam which compresses a spring.

The subject of temperature of water at various depths was discussed by Mr. D. J. Whittemore, President of the Society, who referred to the fact that cold water is frequently obtained by mariners upon the Great Lakes by sinking a corked jug to some depth, and then by withdrawing the cork the jug is filled with water very cold and refreshing.

Observations upon the temperature of the water at various depths in Pine Lake, Wisconsin, were also represented.

Temperature observations upon Lake Superior, show comparatively constant temperature at the bottom, of about 39 degrees, and in depth from 400 to 100 feet.

Observations upon the temperatures of the earth, as shown by deep mines, were presented by Messrs. Hamilton Smith, Jr., and Edward B. Dorsey. Mr. Smith said that the temperature of the earth varies very greatly at different localities and in different geological formations. There are decided exceptions to the general law that the temperature increased with the depth. At the New Almaden quicksilver mine in California, at the depth of about 600 feet the temperature was very high—some 115 degrees, but in the deepest part of the same mine, 1,800 feet below the surface and 500 feet below sea level, the temperature is very pleasant, probably less than 80 degrees.

At the Eureka mines in California the air, 1,200 feet below the surface, appears nearly as cool as 100 feet below the surface. The normal temperature of the earth at a depth of 50 or 60 feet is probably near the mean annual temperature of the air at the particular place. At the Comstock mines, some years since, the miners could remain but a few moments at a time on account of the heat. Some ice water was given them as an experiment; it produced no ill effects, but the men worked to much better advantage, and since that time ice-water is furnished in all these mines and drunk with apparently no bad result.

Mr. E. B. Dorsey said that the mines on the Comstock vein, Nevada, were exceptionally hot. At depths of 1,500 to 2,C00 feet, the thermometer placed in a fresh drilled hole will show 130 degrees.

Very large bodies of water have run for years at 155 degrees and smaller bodies at 170 degrees.

The temperature of the air is kept down to 110 degrees by forcing in fresh air cooled over ice.

Captain Wheeler, U. S. Engineer, estimated the heat extracted annually from the Comstock by means of the water pumped out and cold air forced in, as equal to that generated by the combustion of 55,560 lons of anthracite coal, or 97,700 cords of wood. Observations were then given upon temperature at every 100 feet in the Forman shaft of the Overman mine, running from 53 degrees at a depth of 100 feet to $121\frac{2}{10}$ degrees at a depth of 2,300 feet. The temperature increased:

100 to 1,000 feet deep,	increase	1° in 29 feet.
100 to 1,800 " "	"	1° in 30-5 "
100 to 2,300 " "	"	1° in 32.3 "

A table was presented giving the temperatures of a large number of deep mines, tunnels and artesian wells. The two coolest mines or tunnels are in limestone, namely, Chanarcillo mines and Mt. Cenis tunnel, and the two hottest are in trachyte, and the "coal measures," viz., the Comstock mines in trachyte and the South Balgray in the "coal measures." Mr. Dorsey considered that experieuce showed that limestone was the coolest formation.

Mr. Theodore Cooper gave a description of a curious slide or slump which recently occurred near Dover, New Hampshire, a large section of a clay formation having gone bodily into the adjacent river, moving trees with it but leaving between the river and the cavity a bank of considerable width.

JUNE 4th, 1884.—Vice-President Wm. H. Paine in the Chair, John Bogart, Secretary.

Ballots were canvassed and the following candidates were elicted:—

As Members:—James P. Allen (transferred from Junior), Charleston, S. C.; Henry P. Bell, Winnipeg, Manitoba; William F. Biddle, Philadelphia, Pa.; Wendell R. Curtis (transferred from Junior). Savannah, Ga.; Chauncey Ives, Chambersburg, Pa.; Mace Moulton, Wilmington, Del.; Samuel Rae, Philadelphia, Pa.; Percival Roberts, Jr. (transferred from Associates), Philadelphia, Pa.; Levi L. Wheeler, St. Louis, Mo.

As Associates:—Alan. H. G. Hardwicke, Buffalo, N. Y.; William Roberts, Waltham, Mass.

As Juniors:—William H. Buckhaupt, St. Louis, Mo.; Allan D. Conover, Madison, Wis.; Martin Gay, West New Brighton, N. Y.; Silas B. Russell, St. Louis, Mo.; Chandler D. Starr, New York City.

A paper was read by A. M. Wellington, M. Am. Soc. C. E., giving the details and results of experiments with a new apparatus upon the friction of car journals at low velocities. These experiments were undertaken to test the correctness of a series of tests described in a previous paper, which was made by starting cars from a state os rest down a known grade, and deducing the resistance from the velocity acquired. The present experiments were made by an apparatus in which the axle to be tested is placed in an ordinary lathe having a great

variety of speeds, the resistance of the axle being measured by the levers connected with a yoke encircling the axle, and transmitting the pressures to a suitable weighing apparatus. It was found important that this weighing apparatus should be direct, as for instance, a platform scale rather than a spring scale. The results of these experiments, as to initial friction, were that friction at very low journal speed is abnormally great, and more nearly constant than any other element of friction.

This abnormal increase of friction is due solely to the velocity of revolution. At velocities slightly greater, but still very low, the friction is still large, the co-efficient falling very slowly and regularly as the velocity is increased, but being constantly more and more affected by differences of lubrication, load and temperature. A very slight excess of initial friction would generally be observed. There is no such thing as a journal friction, as a friction of rest in distinction from a friction of motion. The fact that friction of rest appears to exist is due solely to the fact that no journal or other solid body can be instantly set into rapid motion by any force however great. At ordinary operating velocities the character and completeness of lubrication seems to be much more important than the kind of oil used, or even the pressure or temperature.

Comparisons were made of experiments by Prof. Thurston and by Mr. Tower, and the experiments of the author. The rolling friction proper in railroad service seems to be very small indeed, not exceeding one pound per ton. As to the resistance of freight trains in starting, it is believed that the resistance at the beginning of motion,in each journal, is about eighty pounds per ton. A velocity of from one-half to three miles an hour must be obtained before the journal friction falls to ten pounds per ton. At six miles per hour the journal friction is at least one pound per ton higher than at usual working speeds. Temperature exerts a very marked adverse influence upon friction at low velocities. The velocity of lowest journal friction is 10 to 15 miles per hour. With bath or other very perfect lubrication there is a very slight increase of journal friction accompanying velocities up to 55 miles per hour. With perfect lubrication, as with pad or siphon, greater velocity is as apt to decrease as to increase the co-efficient. The latter being more like the ordinary lubrication in railroad service, we may say without sensible error that the co-efficient of journal friction is approximately constant for velocities of 15 to 50 miles per hour.

The paper was discussed by members present.

Engineers' Club of Philadelphia—Special Business Meeting, May 17th, 1884.—Vice-President J. J. deKinder in the chair, the Secretary presented, for Mr. Edward Parrish, an illustrated account of the Effect of Sea Water on the Iron Brandywine Shoal Lighthouse. This Lighthouse was built in 1849-50, near the mouth of the Delaware Bay, and stands in about six feet of water. It is the first screw-pile structure built in the United States, and has but few predecessors in the world. The house is supported on nine piles of hammered iron, surrounded by fifty-two piles of rolled iron, acting as an ice fender. The whole is strengthened by systems of braces and ties. The effect of the water on the iron, continually submerged, has been to produce longitudinal seams or grooves, with occasional holes on the surface; in some cases seriously reducing the strength. The most extensive corrosion is observed on the hammered iron. Round rods in the air are altered in section approximating an irregular polygon with longitudinal grooves.

The Secretary presented, for Mr. Sam'l Rea, "A Treatise on Bridge Architecture in which the Superior Advantages of the Flying Pendent Lever Bridge are Fully Proved," by Thomas Pope, New York, 1811, with Mr. Rea's comments thereuponr.

Prof. L. M. Haupt read an illustrated paper on Rapid Transit, giving valuable data relative to the effects of velocity of movement on the ratio of increase of population, and contrasting the situation in New York and Philadelphia. In comparing the topography of the two cities, a silhoutte of Manhattan Island was laid on a map of Philadelphia (same scale), showing that the island, from the battery to 150th Street, (nine and a half miles), only extended from League Island to Erie Ave. From this it was inferred that, if there was need for elevated roads in New York, there was greater need for them in Philadelphia "as the necessity is proportional to the extent of surface of a city and the distance of its residents from the business centers." The former commercial supremacy of Philadelphia was considered, with the reasons for the rapid decline in the ratio of increase of population, which has diminished from 79 per cent. in the decade 1840-50 to 25 per cent. for 1870–80, whilst Camden's population has increased from 51 per cent. in 1850–60 to 108 per cent. in 1870–80. In short, Philadelphia is overflowing because her time limits of travel are too restricted. Assuming the time limit at thirty minutes each way or one hour per day, at the usual velocities of travel, the limits of the

"Pedestrian City" were found to be a square with diagonals of 4 miles and area 8 square miles.

"Horse Car or Cable City," were found to be a square with diagonals of 6 miles and area 18 square miles.

"Elevated R. R. City," were found to be a square with diagonals of 12 miles and area 72 square miles.

"Underground City," were found to be a square with diagonals of 20 miles and area 200 square miles.

The total area of Philadelphia is 129 square miles, and of the built-up portion 13½, or 10½ per cent. Deducting from the square representing the "street car city," the salient intercepted by the Delaware River, it leaves just the same area, or 13½ square miles, showing the city to have reached the limit of street car travel. The areas benefited vary as the squares of the velocity of travel; hence elevated roads would be worth to the city four times as much as surface lines, and underground roads about eleven times as much. Since 1850 Philadelphia has lost in populatiou one-half a million people equivalent to a revenue on the real estate which

they would have occupied and improved of about $2,000,000 per annum. The two broad zones of the overcrowded portion of the city were also outlined, and the extent of the benefits to be conferred by only two lines of elevated roads were clearly shown by diagrams to extend to the entire city, Elevated roads occupy an intermediate position in cost of construction, rate of travel and general utility between surface and underground structures, and there can be no doubt that the time has fully arrived when this city, *for her own sake*, requires them and should heartily co-operate with any parties so proposing to improve and extend her resources. The following were some of the conclusions arrived at.

1. The city has reached and already surpassed the ordinary limits of street car travel.
2. The ratio of increase of population is rapidly declining chiefly from lack of more rapid and cheaper means of transit.
3. The present steam roads in the city cannot supply the demand as they are surface line trains and must move slowly and cannot be run at close intervals; fares are too high and stations too distant.
4. Camden, N. J., is rapidly gaining population at the expense of Philadelphia.
5. The annual loss to the city in revenue from the cause will reach millions of dollars.
6. Unless relief is afforded the city will be corralled by time limits and the density of the population must increase rapidly at the expense of health and morality.
7. Two lines of elevated railroads at right angles to each other, and properly located, would benefit an area equal to double that of the built up portion of the city.
8. The fears of opponents of elevated roads of losses to the city or the individual, from withdrawal of patronage or depreciation of property, are shown by experience in New York to be groundless.
9. If Philadelphia desires to retain even the present low rate of increase in population, and high rate of salubrity, she must promptly respond favorably to the request of her citizens to be permitted to build elevated roads.
10. The limits of the city are not such as to warrant any corporatian in building an underground road were it recommended or allowed, with any fair prospects of returns, for many years.

Mr. Wm. H. Ridgway read a paper upon the Action of Water in the Modern Turbine, claiming that it is nothing more than an improved Barker's Mill, and that there is no such thing as the water spurting through the shutes and impinging on the buckets as is generally believed, —the wheel on the contrary taking a velocity very much greater than that of the inflowing water.

Mr. J. J. deKinder presented an illustrated description of a method of Removing Condemned Machinery by Dynamite, as practiced by him in the case of the side levers of the old Cornish Pumping Engine at Spring Garden Water Works, Philadelphia, which weighed 29,000 lbs. each. Drilling, tapping and breaking each beam in two, with half a pound of dynamite, and without injury to the building or other machinery, occupied thirteen hours. Even had dispatch been unnecessary, it might have taken two weeks to do this work by the ordinary methods.

The Tellers of Election reported that one hundred votes had been cast, ahd the following gentlemen elected Active Members of the Club.

John H. Converse, W. Henry Sayen, I. Norris DeHaven, Alter Megear, Benj. P. Howell, T. A. M. Matsdaira, R W. Davenport, John N. Pott, J. B. Wilson, Walter C. Brooke, W. Brooks Cabot, Gaylor Thompson, Wm. B. Henszey and Archibald Stevenson.

Regular Meeting, June 7th, 1884.

President Wm. Ludlow in the chair, 27 members and 3 visitors present.

The president announced, in relation to the question of new and enlarged quarters for the Club, that a house could be obtained in the fall, in Girard Street, and requested the members to be prepared to discuss and act upon the subject at the next meeting.

Mr. Wm. H. Ridgway described a simple crane, consisting of a cylinder hung from the jibs of an ordinary foundry crane, and using the steam directly to hoist the load; and also an elevator, in which water, receiving pressure from the direct application of steam acting upon a piston carrying a rack, gave motion to a shaft carrying a pinion and drum wheel.

Mr. C. Henry Roney exhibited specimens of American Sectional Electric Underground Conduits as laid in Philadelphia, described the method of their construction in detail, the difficulties encountered in avoiding the present underground works, the manner of introducing and arranging the wires, and the behavior of the electric currents therein.

Prof. L. M. Haupt supplemented his paper of May 17th, upon Rapid Transit, by an interesting collection of statistics of the growth of the city from the time of the "pack horse" to the present, and showed, by maps, that his previous statements were verified by these statistics.

Mr. A. E. Lehman exhibited to the club a model of a new protractor, and described the invention and the improvements he has made in it. It consists of a combination of protractor, T square, scales, etc., which may be worked separately or together. As a protractor only, it is complete, being graduated to degrees and fractions thereof and provided with a vernier reading to three minutes. It can be used, like an ordinary paper of ivory protractor, for hasty plotting, and combines triangles and scales in one instrument. For careful and precise work it is said to be equal to the best special instrument and to be no higher in price.

Mr. E. V. d'Invilliers read a paper on "Some Characteristics and the Mode of Occurrence of the Brown Hematite (Limonite) Ores in Central Penna," taking for his field of illustration the lower Silurian limestone valleys of Centre Co. He described the anticlinal structure of these valleys, and the great erosion, ærial and sub-ærial, which these rocks (6,000 feet thick) have undergone, influencing the position and character of many of the present

ore deposits. He applied this principle to the different ferriferous limestone beds, and explained how this effect was aided by the alternate rise and fall of the anticlinals along the trend of their axes. He noted three varieties of ore: 1st. The wash and lump hematite of the Barrens. 2d. The true limestone "pipe ore." 3d. An intermediate *transition* variety. The first is always associated with the sandy magnesian beds low down in the series of No. II., or below 5,000 feet beneath the overlying Hudson River Slates of No. III. This class shows rounded ore and flint balls and tough, barren clay, and are secondary or derived deposits of irregular shape. They have been tested 100 feet deep, and contain from 45 to 53 per cent. iron, and .051 to .113 phosphorus. The almost total absence of bisulphide of iron is noticeable. Cost of mining about $1.50 per ton. The *transition* variety was assigned a position in the formation from 3,500 to 5,000 feet below the slates. They are characterized by a more calcareous clay, are compact, amorphous, liver colored ores, containing from 40 to 49 per cent. iron and from .115 to .365 per cent. phosphorus. The *pipe ores* occur usually higher in the limestones than either of the other two. but in this country *below* tbe 400 feet of upper Trenton layers. These ores occur *in situ*, between parallel walls of limestone; in plate-like masses, scales, or as cylindrical pipes in bunches 8 or 10 feet long, while feathering out both in line of strike and dip. The deeper banks show the repeated occurrence of crystals of iron pyrites in all stages of metamorphism. They occur at great depths, and show from 45 to 53 per cent. iron and from .100 to .185 per cent. phosphorus. The flint or quartz grains accompanying them are rarely water worn, and this clay is very calcareous and easily washed, not requiring the jigging necessary for cleansing the lower ores. Cost of mining these ores varies from 90 cents to $1.25 per ton.

Prof. L. M. Haupt called the attention of the club to a bill, pending in Congress, to consolidate the U. S. Coast and Geodetic Survey with the Navy Department.

Captain S. C. McCorkle, of the Coast Survey, who was present, explained the effect that its passage would have upon the future of the work, and President Wm Ludlow gave, from his own experience and knowledge, tbe reasons why this change was contemplated. The Secretary read his correspondence with Hon. Sam'l. J. Randall upon the subject, and expressed what he believes to be the unanimous sentiment of the Civil Engineering profession of the country, against any interference with a Survey, the perfection of whose results is proverbial, and against any increase of the already unwise and unjust discrimination of the Government against thoroughly competent *Civil* Engineers, and in favor of a class who often (but with *notable* exceptions) have, comparatively, but little ability, and whose only claim is that the Government has attempted to educate them, and must, therefore, seem to provide them with something to do.

Michigan Association of Surveyors and Civil Engineers.—Contents of Proceedings: Third meeting.

I. History of Legislation for Surveyors.

II. Foundations and Piers of the Wheeling & Lake Erie Railroad Bridge, at Toledo, Ohio. By Prof. Chas. E. Green.

III. Water Works for Small Cities. By G.W. Pearsons, Kansas City, Mo.

IV. Reform School for Girls. By Burton Kent, Adrian.

V. Compass Deviations on Vessels and the Conversion of Compass Courses. By H. C. Pearsons.

VI. Drainage Engineering. By R. C. Carpenter.

VII. Practical Questions. By J. H. Leavenworth.

VIII. Horizontal and Vertical Distances Without the Use of a Vertical Arc or Stadia Wires. By H. C. Pearsons.

Contents of Proceedings: Fourth Meeting.

Legislative Needs of Surveyors. By George E. Steele.

The North Lansing Mill Dam. By A. D. Bartholemew.

Wooden Pavements. By H. G. Rothwell.

Water as a Source of Engineering Difficulty. By Prof. Chas. E. Green.

Common Roads. By Burton Kent,

Difficulties in City Surveying. By A. J. Teed.

Logging Railroads. By E. F. Guild.

Practical Questions. By J. H. Leavenworth.

Necessary Instruments for Surveyors. By Prof. J. B. Davis.

Surveying for Railroads. By F. Hodgman.

Projection of a Parallel of Latitude. By H. C. Pearsons.

Traverse Surveying. By Prof. J. B. Davis.

Engineering of Town and County Drains. By S. N. Beden.

A Level Line of Sight. By Prof. J. B. Davis.

The Judicial Functions of Surveyors. By Justice Cooley.

ENGINEERING NOTES.

A Board of Trade report has been published on the works in progress for the construction of the bridge over the river Forth, from which it appears that the most important works at South Queensferry consist of the coffer dams for the south cantilever pier and for No. 7 viaduct pier. The former is composed of two rows of 12in. sheet piling, with outside struts bearing against the piles, and sustained internally by heavy cross timbers. The dam measures 115 ft. by 65 ft. inside, and the piles, which average 47 ft. long, are driven about 21 ft. into the ground. With a view to safety and expedition the dam has been divided into two halves; the eastern half is completed, the water pumped out, and a trial pit sunk in the center to ascertain the depth of the hard clay; at a depth of 9 ft. below the surface, and 12 ft. below low water of spring tides, a compact layer of boulders, averaging 18 in. thick, was reached, and immediately below this the hard boulder clay was entered, which appears to be very stiff and compact. The piles of the western half of the dam are nearly all driven, and it is expected

that the water will shortly be pumped out and the excavation commenced. About 96,000 cubic feet of granite have been delivered, of which 64,000 cubic feet have been set, and about 8,000 cubic yards of concrete are now in position.

After full consideration of about twenty plans of sewerage and sewage disposal, submitted by different engineers, for the district of Southall and Norwood—Middlesex—the Uxbridge Rural Sanitary Authority, has decided on that prepared by Mr. John Anstie, C.E., of Westminster-Chambers, and proposes, subject to the approval of the Local Government Board, to commence the works as soon as arrangements can be made for purchase of the lands required for the disposal of the sewage, which belongs to the Earl of Jersey. The scheme provides for the main sewerage of a district about four square miles in area, with a view to a considerable portion of it being hereafter built upon, the disposal of the sewage being effected by means of precipitating tanks, and subsequent natural filtering of the water through an area of land specially prepared. The undertaking is estimated to cost about £10,000.

A trial was recently made at Messrs. Grant, Ritchie & Co.'s works, Kilmarnock, of one of Mr. Joseph Moore's patent hydraulic pumps. In these pumps there are no pump rods, and in their place there are two pipes of small diameter, in which is contained water under a pressure of 1,000 lbs. per square inch. This water serves as a hydraulic rod for transmitting the power from the engine on the surface to the pumps underground, and enables the pumps to be placed round any number of turns and at any distance from the engine. The pump which Messrs. Grant, Ritchie & Co. tested is for the Broxburn Oil Company. The engine will be placed on the surface and the pump down a drift 300 yards long. The vertical lift will be 720 ft. In the trials the pnmp was placed 120 ft. from the engine, and water was discharged at a pressure of 200 lbs. per square inch. It worked throughout very smoothly and efficiently. The system is also suitable for sinking, in which case the columns of pipes and the plungers slide in wooden guides in the same manner as a cage. They are suspended by two sets of rods from a hydraulic ram, which raises and lowers the pumps and pipes in the sinking process.

IRON AND STEEL NOTES.

Herr W. Hupfeld, an engineer of Prevali, Austria, recently published the results of a series of experiments on welding steel in the *Oestreichische Zeitschrift fur Berg-und Hutten-Wesen.* He instances the fact that the Austrian navy, in its specifications for steel angles, has a welding test which will certainly be conceded to be severe. One of the sides is cut, the angle is bent at right-angles, the flaps are welded together, and, when cold, the angle is again bent straight. This test the Austrian Bessemer steel will stand, the material having from 0.20 to 0.25 carbon, and a tensile strength of from 40 to 50 kilogs. During twenty-seven blows, Herr Hupfeld cast two sample ingots 70 mm. square and 300 mm. long, one of which was used for the welding test, and the other for the corresponding test of metal not welded. One ingot was cut in two, and a butt well made, each end being tapered so that, put together, they had a bearing surface of 70 mm. Then, after a second low heat, the welded part was forged under a steam hammer to 20 mm. square, and the rod turned to a diameter of about 15 mm., and well polished. When tested the bars yielded results which showed hardly any deterioration through welding. Phosphorus, the *Engineering and Mining Journal* mentions, was in no case above 0.045, and sulphur not over 0.02 per cent. The tests show that by welding the tensile strength is, on an average, diminished by only 1.75 per cent., the maximum being 5 per cent., and that the ductility is increased by exactly the same amount.

Protecting Steel and Iron from Rust.—Professor Calvert has recently made the interesting discovery by practical tests, that the carbonates of potash and soda possess the same property of protecting iron and steel from rust as do those alkalies in a caustic state. Thus it is found, that, if an iron blade immersed in a solution of either of the above carbonates, it exercises so protective an action, that that portion of the iron which is exposed to the influence of the damp atmospheric air does not oxidize, even after so extended a period as two years. Similar results, it appears, have also been obtained with sea-water, on adding to the same the carbonates of potash or soda in suitable proportion.

A Fine Finish for Steel.—A Fine lusterless surface on tempered steel can be procured by either of the following operations: After the steel article has been tempered, it should be rubbed on a smooth iron surface with some pulverized oil-stone, until it is perfectly smooth and even, then laid upon a sheet of white paper, and rubbed back and forth until it acquires a fine dead finish. Any screw-holes, or depression in the steel, must be cleaned beforehand with a piece of wood and oil-stone. This delicate, lusterless surface is quite sensitive, and should be rinsed with pure soft water only. A more durable finish is obtained by smoking the steel surface with an iron polisher and some powdered oil-stone, carefully washing and rinsing; then mix in a small vessel some fresh oil and powdered oil-stone; dip into this mixture the end of a piece of elder-pitch, and finish the steel surface with a gentle pressure, cutting off the end of the pitch as it commences to become soiled. In conclusion, it should be thoroughly cleaned in soft water, when the article will be found to have a fine lusterless finish.—*Popular Science Series.*

RAILWAY NOTES.

"Instructions with reference to Sanders-Bolitho automatic vacuum brake" on the Midland Railway have been issued, which show that it is not an automatic brake. One paragraph says:—"In the event of a train becoming divided when going up a rising gradient, the

guard must, in addition to turning the tap to the 'remain-on' position, also apply his hand brake tightly, and take such other measures as may be necessary to prevent the vehicles from moving."

The gauge in India controversy is opening up a burning topic, and the battle of the gauges will have to be fought again. There are no less than five railway gauges in India—the 5 ft. 6 in., or broad gauge, the 3 ft. 3 in., or meter gauge, the 4 ft. used on the Azimganj Railway, the 2 ft. 6 in. gauge of the Gaekwar of Baroda's line, and the 2 ft., or military gauge of the Himalayan Railway. Practically the contest now lies between the broad and meter gauges; the most important lines have been laid on the former, and the broad gauge is the proper one to survive. What is now desired is uniformity, as the present breaks of gauge, and consequent shifting of goods add considerably to the cost of transport, though Indian railways now pay.

In a report on an accident, which occurred on the 28th February, at Fenchurch street station on the great Eastern Railway, when, as a passenger train was entering Fenchurch street station, the engine left the rails with all its wheels at the sharp curve leading from the right-hand up line to No. 5 platform line, and was stopped after running about 49 yards, Major-General Hutchinson says:—"The train consisted of an eight-wheeled tank engine, with a four-wheeled trailing bogie, and a train of twelve vehicles, fitted throughout with the Westinghouse brake. This accident, which is almost a repetition of those which occurred at the same spot last October, must, I think, be attributed to the speed having been too high round the sharp curve of five chains radius, and to the gauge at the points being unnecessarily tight, the result being that the left leading wheel of the engine left the rails at the outside of the curve, having crossed the left switch 15 in. from its tip."

While Germany has 21,865, England 18,685, and France 18,050 miles of railway, Turkey has only 1,015 miles, though her population is almost as numerous as that of these three countries. There are four lines of railway now open for traffic, the most important being the Roumelian lines, which are 730 miles long; and upon which, in 1881—the last year for which statistics have been given—the receipts were £587 a mile. The Smyrna, Cassaba and Alachur Company has 295 miles of railway, which in 1881 carried 395,000 passengers and 470 tons of goods; its receipts being £1,125 to the mile. The Aidin Company has 120 miles of railway, and carried 190,000 passengers and 500,000 tons of goods; its receipts being £1,088 to the mile. The Haidar Pasha line is 58 miles long, and its receipts in 1881 were £573 per mile. There is also a short line, 26 miles long, from Mondavia to Broussa, which was opened a few years ago. But it has been allowed to fall into disuse, and the inhabitants of the district through which it passes are using the sleepers as firewood, and the rails themselves to brace up their houses. Four new lines are now in course of construction.—*Engineer.*

ORDNANCE AND NAVAL.

Casting Cannon for the American Government.—A 12-inch rifle mortar, intended as an experimental gun, was cast recently, by the South Boston Ironworks. This is the beginning of renewed activity in gun-making after a period of seven years, during which this portion of the plant has lain idle. This is the first of five heavy experimental guns contracted for by the Ordnance Department last September. The other guns will be cast shortly. One will be a 10-inch breech-loading rifle, the body to be of cast iron, which is to be reinforced by a wrapping of steel wire. Another will be a 12-inch breech-loading rifle entirely of cast iron, and is to weigh, when finished, some 57 tons. The fourth is to be like the last in all respects, with one exception, that it is to be lined from the breech with a short steel tube, to reach a little beyond the trunnions. The fifth is to be a 12-inch breech-loading rifle, the body to be of cast iron, but to be reinforced by steel rings around the breech, and to be lined the full length with a steel tube. The material used in all the castings will be the Salisbury charcoal iron, mined and smelted in Western Massachusetts. The guns are cast on the rodman system. The South Boston Ironworks have also contracted with the Navy Department for the breech-loading rifles to armor the new cruisers which John Roach is now building.

The Chinese war steamer, Nan Thin, which was lately detained at Newcastle-on-Tyne, by order of the British Government, was built by Mr. George Howaldt, of Kiel, and was launched in the latter part of last year. The vessel was not built for the Imperial Government, but for the Viceroy of Canton, who possesses a small navy of his own. She is a steel-built corvette of 2,200 tons, and is barque rigged. Her principal dimensions are: Length between perpendiculars, 277 ft.; breadth, extreme, 38ft.; depth in hold, 23ft. 4in.; draught of water, 18ft. She is propelled by twin screw engines of 3,000 indicated horse-power, manufactured by her builder, and she is said to steam at the rate of 14½ knots per hour. Her armament consists of two 9in. and eight 40-pounder breech-loading Armstrong guns, and it was for the purpose of taking these on board that she proceeded to Newcastle. The action of the British Government in embargoing this vessel has created much surprise on the Continent, as no valid excuse can be found for her detention. It is maintained by competent authorities that the German Government only is responsible for any breach of international law which may have been caused by her departure from a German port. It will be remembered that Mr. Howaldt was the builder of the *ci devant* Peruvian cruisers, Diogenes and Socrates, which were first seized at Kiel by the German, and subsequently at Southampton by the British Government.—*Engineer.*

THE NEW SCREW GUN VESSEL FOR THE NAVY.—On the 7th May H. M. S. Reindeer, screw gun vessel, which was built at Devonport and launched in November last, was taken into the Channel for a peliminary trial of her machinery, which has been fitted by Messrs. R. and W. Hawthorn, St. Peter's Works, Newcastle. The Reindeer is one of five vessels of a class which is an improvement on the Dolphin and Wanderer, recently commissioned at Sheerness. Four of the ships, including the one tried, have been or are being constructed, at Devonport, those on the stocks at present being the Mariner, Racer, and Icarus. The fifth, the Acorn, is being built at Pembroke Dock. The Reindeer is fitted with six 5in. guns, two on either slde, one forward, and the other aft. When the start was made the weather was very threatening, and before the ship had been long outside the wind rose to a gale. Nevertheless the trial proceeded very smoothly, the machinery working splendidly throughout. The engines are horizontal, compound, surface condensing, with high cylinder 32in. and low 54in. in diameter. with 3ft. stroke. The engines are fitted with Mr. F. C. Marshall's patent valve gear, having one eccentric only for each cylinder, which reduces the number of working parts to a minimum. The engines are so arranged as to cut off steam between 17 per cent. and 60 per cent. of stroke without expansion valve. The ship is fitted with three boilers 7ft. 2in. diameter by 16ft. 9in. long. When the trial commenced the steam in the boilers was 90 lb., the vacuum in the condensers 26.25in., the mean revolutions per minute 74, mean pressure in the higher 9.8 lb., in the low cylinder 12.4 lb. For one hour the engines were woeked as the highest grade of expansion, giving 106 horse-power in the high-pressure, cylinder and 384 in the low-pressure cylinder—total 490. The engines were then worked at different grades of expansion with satisfactory results. The machinery was then gradually worked up to full power, the steam in the boilers being 82 lb.; the vacuum in the condensers, 26in.; revolutions 96 per minute ; mean pressure in the high cylinder, 23 lb.; in the low cylinder, 14.3 lb.; giving an indicated horse-power, high, 322; low, 572—total 894. The engines were next tried at one hour jet injection. The mean steam in the boilers was 75 lb., the vacuum in the condensers, 19in.; revolutions, 75.8 per minute; mean pressure in the high cylinder, 17.4 lb., in the low cylinder, 11.4 lb.; horse-power, high, 193; low, 361—total, 554. Stopping and starting were next tried. The engines going full speed ahead were stopped in three seconds; being stopped, they were started astern in three seconds; going astern, they were stopped and started ahead in five seconds.—*Engineer.*

BOOK NOTICES

PUBLICATIONS RECEIVED.

SIGNAL SERVICE NOTES:

No. VI. Report on Wind Velocities at the Lake Crib and at Chicago. By H. A. Hazen.

No. VII. Variation of Rainfall West of the Mississippi River. By H. A. Hazen.

No. VIII. The Study of Meteorology in the Schools of Germany, Switzerland and Austria. By Frank Walds.

No. X. Report on the Lady Franklin Bay Expedition of 1883. By Lieut. Ernest A. Garton. Washington: Signal Office.

From Mr. James Forrest, Secretary of the Institution of Civil Engineers, we have received the following papers of the Institution:

The Adoption of Standard Forms of Test Pieces. By William Hackney, A. I. C. E.

Wood-working Machinery. By James Bernard Hunter.

Speed on Canals. By Francis Roubillac Conder, M. Inst. C. E.

Two Applications of Calculation to the Resistance of Materials. By Charles Antoine, of Brest.

The Theory of the Dynamo-Electric Machine. By Randolph Clausius, Hon. M. Inst. C. E.

Abstracts of Papers, Vol. 74, part 4.

Monthly Weather Review for April. Washington: Signal Office.

School of Mines Quarterly for May.

Report to U. S. Commissioner of Fisheries; with Plans for the Fishways of the Great Falls of the Potomac. By M. McDonald.

Report of the Board of State Engineers of the State of Louisiana for 1882–83. Baton Rouge: State Printer.

SYMBOLIC ALGEBRA, OR THE ALGEBRA OF ALGEBRAIC NUMBERS. By PROF. WM. CAIN, C. E. Van Nostrand's Science Series. No. 73.

This essay will prove of special interest to teachers and pupils of elementary algebra, the vexed question of negative quantities being the single topic of the first half of the book. Nothing could be clearer than the author's exposition of the system of symbols which avoids the difficulties encountered by students or teachers who are hampered by arithmetical conceptions.

A second essay in the same book relates to the methods of geometry, and will prove equally serviceable and interesting to the same class of readers. The principles discussed are not so rudimentary in character, but the explanation is of such a nature that students of elementary mathematics may read it with profit; indeed, these essays form a part of the author's course as an instructor in the Military Academy of Charleston, S. C.

TESTING MACHINES: THEIR HISTORY, CONSTRUCTION AND USE. BY ARTHUR V. ABBOTT. Van Nostrand's Science Series, No. 74. New York: D. Van Nostrand.

The testing machine is a modern invention. Economy of material is a matter of recent study. Only modern engineers have applied methods of calculation to determine the limits within which they can successfully build; the limits involving safety and durability on one hand, and clumsiness and wastefulness on the other. The data for such calculation can be properly furnished only by the testing machine.

The development, construction and use of such machines is graphically set forth in this little essay. Evidence of careful study of the subject is manifest throughout the book.

The illustrations are numerous and excellent.

REPORT OF THE CHIEF OF ORDNANCE TO THE SECRETARY OF WAR FOR THE YEAR 1883. Washington: Government Printing Office.

Like ordinary official reports, this one presents its chief value in its appendices. Up to "Appendix 9" there is nothing that is intended to be read probably by anybody. From Appendix 10 to Appendix 42, inclusive, there is much relating to systematic trials of materials and of guns that will be regarded with interest wherever the art of war is a subject of study.

There are many illustrations of different kinds and all degrees of excellence scattered throughout the volume.

INTRODUCTION TO THE STUDY OF MODERN FOREST ECONOMY. By JOHN CROUMBIE BROWN, LL.D. London: Simpkin, Marshall & Co.

Few writers have done as much to advance the plans of preserving forests as the author of this treatise. He was one of the first to collect statistics exhibiting the full measure of the evil resulting from destruction of forests.

The general principles of preserving and restoring forests are compactly stated in this last essay. The newly-awakened interest in this subject in the United States should ensure a wide reading of it..

A MANUAL OF CHEMISTRY—PHYSICAL AND INORGANIC. By HENRY WATTS, B. A., F. R. S. Philadelphia: P. Blakiston & Co.

This book is designed to take the place of the well-known "Manual of Chemistry" of the late Professor Fownes. Like that widely-known text book it presents a complete outline of chemical physics and inorganic chemistry.

A short sketch of the more important elementary bodies commences the volume. The Laws of Combination, the Rules of Nomenclature then follow, and then in order come Heat, Light, Magnetism and Electricity, which closes the first part.

Part second, which is about two-thirds of the bulk of the volume, contains Inorganic Chemistry on the familiar plan of ordinary English text-books.

The careful and even elaboration of the successive topics which gave the old book its value seems to have been carefully preserved in the present edition. In some places the new editor has failed to preserve the precision of the old book. This is especially noticeable in some of the definitions of scientific terms.

A SHORT TEXT BOOK OF INORGANIC CHEMISTRY. By DR. HERMANN KOLBE. Translated and edited by T. S. Humpidge, Ph. D. New York: John Wiley & Sons.

"The problem of the lecturer on chemistry," says Dr. Kolbe in his preface, "is to give his hearers an idea of chemical processes, and the most important chemical theories, without burdening their memories with a large number of mere facts, and thus to prepare them to acquire an accurate knowledge of chemistry by their own practical work."

With this principle constantly in view this text book has been carefully prepared. Chemical reactions and processes are given only to illustrate the principle or law of combination,

The science as elucidated is in accord with the latest discoveries. The illustrations are few in number but good.

ELECTRICITY: ITS THEORY, SOURCES AND APPLICATIONS. By JOHN T. SPRAGUE, M. S. T. E. London and New York: E. & F. N. Spon.

Judging from the numerous inquiries which have been made, many of our readers will be glad to hear that the long-promised second edition of this work is now issued. The new edition is greatly enlarged, the 384 pages of the first having now grown to 650, forming a substantial volume of well and closely-printed matter, inclosed in a handsome binding. We see that all that was in the first edition is reproduced, though with some rearrangement and revision; therefore, the work retains the special character which distinguishes it from all other electrical books, and which rendered it so welcome and useful to that great class of students of electricity who are not familiar with mathematical formula, and either dislike, or can not master the abstract theories of the text books. This is indicated by a statement in the preface: "There are two electricities known to the scientific world: the electricity which exists in nature, and the electricity which, created by mathematicians, exists chiefly upon the blackboards of the professor's class-room. It is the first of these electricities which this work endeavors to elucidate." But this second edition carries the reader further in the direction of mathematical electricity than the first one did, as the section in Measurement fully explains the centigrade system, and we note that the term "potential" is not repudiated as in the first edition, though not allowed to displace the simpler "electromotive force." Its meaning also is fully discussed, and its relation to energy explained.

The chapter on static electricity is considerably extended, particularly in connection with inductive capacity, and the latest improvements in the Voss and Wimshurst machine are described. The chapter on batteries has not been much altered, as every useful form was already fully explained: but a full description of secondary batteries is added to it, derived from the series of articles which appeared in our pages, and in which all the most trustworthy information on the subject was furnished.

The chapter on measurement is largely re-written, and we see that Mr. Sprague has included in it the results of his own investigations in galvanometry and the mode of graduation he has devised for his patent galvanometers, which will no doubt be of interest to many. The sections on electrolysis and metallurgy have undergone little change—indeed, they were already so complete that there was little need for change.

The original chapter on Lightning has been extended into a more general one on Terrestrial Electricity, in which we see a statement which will probably be challenged, viz., that "there is good reason to believe that nothing resembling electrical action occurs across space," and that neither the earth nor any of the other orbs have a static electric charge; this doctrine

would be inconvenient for the many theorists who can now utilize electricity as an explanation for anything they do not understand; but it is defended by the argument that if such charges existed "gravitation could not be a constant force." A very full description is given of the principles of dynamo-machines, including the principle of compounding and the use of the "characteristic curves," their efficiency as also that of electro-magnetic motors, and the cost of current and work derived from them.

A chapter of 34 pages on electric lighting is entirely new, and contains a great deal of information as to the nature of light and its relation to electricity, as well as the practical processes and apparatus employed, and the cost of obtaining the light, as to which the sound remark is made that this is one of those matters in which a little knowledge is a dangerous thing.

Telephones, radiophony, the induction balance, and the latest discoveries are fully explained in one chapter, together with a sketch of the leading principles of thermo-electricity, and the dictionary of terms, which gives convenient definitions for reference, concludes a work which may fairly be described in the words of an American professor, quoted among other critics: "The principles of the science and the operations of its laws are given with a perspicuity and fullness of exposition rarely to be met with. It is not too much to say that the laws of the correlation of the forces are here worked out in a manner exceptionally impressed with originality. . . . The work is pregnant of valuable thought, and should be read by all who seek to get a firm grasp upon the fundamental principles of the science."

An ample index is supplied, and we note that our suggestion in reviewing the first edition has been adopted, and that a copious table of contents has been added to the present edition. *English Mechanic.*

ABSOLUTE MEASUREMENTS IN ELECTRICITY AND MAGNETISM. By ANDREW GRAY, M.A., F. R. S. E., Chief Assistant to the Professor of Natural Philosophy in the University of Glasgow. London: Macmillan and Co.

A want is felt in physical laboratories for a work that may serve a student as a guide through the various departments of electrical and magnetic measurements. Kohlrausch's "Introduction" contains much useful information, but it is put together in a manner that is not always clear and satisfactory. Kempe's "Handbook" is very good for the special purpose for which it was written, for it meets in a complete manner all the requirements of electric telegraphy. It is expected that the forthcoming volume by Professors Mascart and Joubert will in some measure supply our deficiency.

Mr. Gray's book is not introductory; it presupposes a good acquaintance with the laws of electrical and magnetic quantities, and the methods of measurement in general use. Nor is it a complete treatise; it was written for the specific purpose of giving, by a few well-chosen and typical measurements, a clear account of the absolute system of units now universally adopted.

As illustrating magnetic measurements, we have a detailed explanation of the Gaussian method of determining the horizontal component of the earth's force. This naturally leads to definitions of the magnetic units and elements.

The theory of the ring tangent galvanometer follows, nothing, however, being said of the double-coil arrangement of Helmholtz now generally adopted in standard instruments. In developing the theory of the several instruments described, the author does not hesitate to discard unwieldly elementary methods, and uses where necessary the more rapid and powerful formulæ of the integral calculus.

Due prominence is given to the comparatively new instruments—the graded galvanometers—of Sir William Thomson. The theory of each is explained and several ways are described by which they may be graduated and their accuracy easily verified at any subsequent time.

The comparison of resistances occupies a chapter of thirty pages, in which are discussed such important matters as the sensitiveness of the Wheatstone bridge and Kirchoff's modified form of it, the elimination of the effects of self-induction, the calibration of wires, the measurement of high resistances, the insulation of the electrometer, and the internal resistance of batteries.

We notice, in connection with this chapter, that no reference is made to Professor Forster's elegant method of calibrating wires, or to the various condenser methods for determining what is called the resistance of a battery.

Another chapter of the book treats of the development of energy in the various parts of an electric circuit. It contains much useful information about many points relating to dynamos and electric motors which one would look for in vain in text-books published a year back. This information is obtainable from first sources only, being scattered over the proceedings of many societies; and Mr. Gray has done a serviceable work in giving briefly the conclusions of the more important investigations that have been carried on. The efficiency of machines is defined, its relation to speed and resulting potential pointed out, a convenient form of ergometer is described, and a sketch of the theory of alternating current, machines is given including the effects of self-induction.

This latter theory is confessedly a difficult subject, and one could not expect of Mr. Gray more than a brief reference to the several variables which lead up to that very complex integral, viz., the current from a dynamo or an alternating current machine.

The concluding chapters deal with the measurement of intense magnetic fields, magnetic permeability and susceptibility, and the various electro-static and electro-magnetic units.

If we had to point out any part of this excellent little book which appeared to us wanting in clearness, we should indicate the early paragraphs of Chapter X. We think a clearer exposition is possible of the meaning and methods of measurement of the efficiency of dyna-

mos and motors, and also of the precise conditions required for rapidity and economy of working respectively.

Undue importanee seems to be attached to the copper voltameter. We may mention that Lord Rayleigh found it unreliable for accurate measurement, and hence the adoption of the silver voltameter for delicate work.

Mr. Gray states as the result of many careful determinations made in the University of Glasgow by Mr. Thomas Gray, that a coulomb liberates at the negative electrode, .000331 of a gramme of copper. This would make the electro-chemical equivalent $e = .00331$, whilst if we take the e of silver as determined quite recently and with extreme care both by Lord Rayleigh and by Kohlrausch as .01118, the electro-chemical equivalent of copper as deduced therefrom would be .00344.

To one who has already a good knowledge of electrical matters generally, and some experience in a physical laboratory, the work of Mr. Gray will be of great help. Written by a man who is practically familiar with his subject, and who enjoys the advantage of everyday intercourse with Sir William Thomson, it is replete not only with theoretical information, but it is also very suggestive of "means and ways."—*Engineering.*

MISCELLANEOUS.

The Electro-Chemical Equivalent of Silver.—A very careful and important determination of the electro-chemical equivalent of silver has been made at the Observatory of the Physical Institute of Wurzbourg, and the results are that an ampere current flowing for a second, or a coulomb of electricity deposits 1.1183 milligrammes of silver or 0.3281 milligrammes of copper, and decomposes 0.09328 milligrammes of water, a result agreeing closely with that of Lord Rayleigh recently communicated to the Physical Society. An ampere therefore deposits 4.0259 grams of silver per hour; Kohlrausch's value is 4.0824, a value hitherto accepted universally. This value is so useful in measuring electric currents with accuracy, and free from the disturbances of magnetism, &c., that it is eminently satisfactory to find the German value agree with that of Lord Rayleigh, which will probably be adopted by English electricians.

When a casting is very thin, even if of soft grey pig, it is often as hard, even though run in sand, as if cast in a chill. Such castings may be annealed, so that the surface may be worked, by putting them in boxes and raising the temperature to redness. In the case of gray iron the castings are surrounded with coarse sand, and heated for forty-eight hours; but in that of white iron they are surrounded by a mixture of one part of sal-ammoniac and twelve parts of hammer scales, and heated for twenty-four hours. This length of time is sufficient to soften the skin; but if the operation be continued for a week the castings will become malleable.

The following formula has been given for a convenient ink for marking, by means of a stamp, textile articles that have to be washed: Twenty-two parts of carbonate of soda are dissolved in 85 parts of glycerine, and triturated with 20 parts of gum arabic. In a small flask are dissolved 11 parts of nitrate of silver in 20 parts of officinal water of ammonia. The two solutions are then mixed and heated to boiling. After the liquid has acquired a dark color, 10 parts of Venetian turpentine are stired in it. The quantity of glycerine may be varied to suit the size of the letters. After stamping expose to the sun or apply a hot iron.

A New Standard Light.—Her Heffner-Alteneck has suggested a new standard light for photometric purposes, which promises, to be very simple and effective in operation. The light is produced by an open flame of amyl-acetate burning from a wick of cotton fiber which fills a tube of German silver 1 in. long and 316 mils. internal diameter; the external diameter being 325 mils. The flame is 1.58 in. high from top to bottom; and it should be lighted at least ten minutes before using the light for testing. A cylindrical glass chimney surrounds it to ward off air currents. About 2 per cent. of the light is absorbed by the glass. The power of the flame is that of a standard English candle; and experiments have shown that amyl-acetate, which besides is not expensive, is the best fuel for steadiness and brilliance. Neither substitution of commercial amyl-acetate for pure, nor the use of wick of cotton thread for loose cotton fiber alters the illuminating power; but the wick should be trimmed square across the mouth of the tube, for if it project and droop the illuminating power is increased.

A standard thermopile.—Dr. G. Gore, F.R.S., has invented an improved thermopile for measuring small electromotive forces. It consists of about 300 pairs of horizontal, slender, parallel wires of iron and German silver, the former being covered with cotton. They are mounted on a wooden frame. About $1\frac{1}{2}$ in. of the opposite ends of the wires are bent downwards to a vertical position to enable them to dip into liquids at different temperatures contained in long narrow troughs; the liquids being non-conductors, such as melted paraffin for the hot junctions, and the non-volatile petroleum, known as thin machinery oil. The electromotive force obtained varies with the temperature; a pile of 295 pairs having a resistance of 95.6 ohms at 16 deg. Cent., gave with a difference of temperature of 100 deg. Cent., an electromotive force of .7729 volts, or with 130 deg. Cent. an electromotive force of 1.005 volt. Each element, therefore, equaled .0000262 volt for each degree Cent. difference of temperature, On having been verified with a standard voltaic cell the apparatus becomes itself a standard, especially for small electromotive forces. It is capable of measuring the $\frac{1}{34861}$ part of a volt. For higher electromotive forces than a volt, several of these piles would have to be connected in series. The fractional electromotive force is obtained by means of a sliding contact which cuts out so many pairs as is required.

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EXPERIMENTS ON THE EFFICIENCY OF INCANDESCENT ELECTRIC LAMPS.

By HORACE B. GALE, Natick, Mass.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

II.

METHOD OF COMPARING CURRENTS.

There were thus two simultaneous measurements of current to be made. As there was, however, but one reliable ammeter at the writer's disposal, an arrangement was devised by means of which the strength of two electric currents—for example, the current through the lamp and the current through a resistance coil in derivation with the lamp—could be compared with each other by means of the Wheatstone's bridge.

As this method is the most accurate one known to the writer for comparing strong currents of electricity, and as it requires no special apparatus except an ordinary Wheatstone's bridge, it will be described in full, in the hope that other experimenters may find it useful. The arrangement will be understood from the accompanying diagram. Fig. 11.

The current C from the dynamo passes through the ammeter, and divides at the point *a* between the two branches *abe* and *ade* of the circuit, one portion of the current whose strength is denoted by C_1, passing through the resistance coil R, and the other, C_2, passing through the lamp, which stands in its place at the end of the photometer bar. *be* and *de* are two coils of heavy copper wire of small resistance, but exactly equal to each other; the resistance of each being denoted by R_3. After traversing these coils, the currents C_1 and C_2 unite at *e*, and return to the dynamo. *dc* and *ce* are two arms of the Wheatstone's bridge, whose resistances are marked R_2 and R_1. The bridge proper, containing the galvanometer, is from *b* to *c*, the circuit through it and the resistance coils R_2 and R_1 being closed in the ordinary manner by a double key, at *c*. When the key is closed, a small portion of the current C_2 is shunted around *de* through the coils R_2 and R_1 of the bridge. This current is denoted by C_3. Then the current passing through the portion *de* of the circuit is C_2-C_3, as indicated in the diagram.

In using the apparatus, the arm R_1 is made a certain fixed resistance, say 1,000 ohms. The resistance R_2 is then adjusted, until, on pressing down the key, no current passes through the galvanometer. The points *b* and *c* are then at the same potential. It follows that the difference of potential from *b* to *e* is the same as the difference of potential from *c* to *e*. But the difference of potential, or the electromotive force, between two points of a circuit is the product of the current and the resistance between those points.

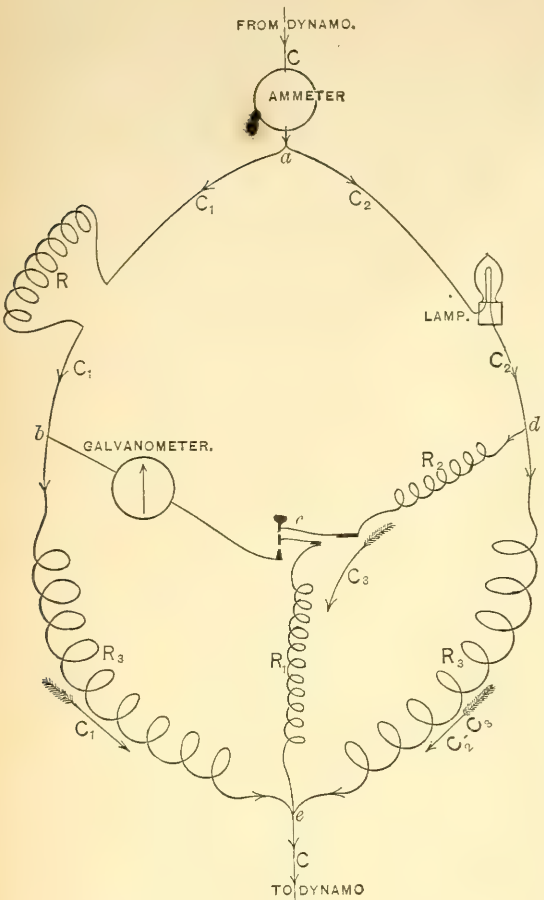


Fig. 11

Therefore $C_1R_3=C_3R_1$, or $C_3=\dfrac{C_1R_3}{R_1}$.

Our purpose, it should be remembered, is to ascertain for each lamp the variation in candle-power and current strength as the electromotive force is increased; for which object it is necessary to vary the candle-power by a series of steps, and take simultaneous observations of the current and electromotive force at every point. Knowing, in each case, the value of the total current, C, if we can find the ratio between the currents C_1 and C_2 traversing the two main branches of the circuit, we shall have, not only the current flowing through the lamp, C_2, but—by multiplying the resistance of the branch *abe* by C_1—we may obtain the electromotive force.

Our object is now to find the ratio between the currents C_1 and C_2. It is evident that the electromotive force from *d* to *e* is equal to the sum of the electromotive forces on *dc* and *ce*; or using instead the products of the currents and resistances on these branches, we have

$$(C_2-C_3)\,R_3=C_3\,(R_2+R_1)$$

Substituting for C_3 its value $\dfrac{C_1R_3}{R_1}$ previously found, we have

$$\left(C_2-\frac{C_1R_3}{R_1}\right)R_3=\frac{C_1R_3}{R_1}\left(R_2+R_1\right)$$

Clearing of fractions,

$$C_2R_1-C_1R_3=C_1R_2+C_1R_1$$

Transposing and combining,

$$C_2R_1=C_1\,(R_1+R_2+R_3)$$

or

$$\frac{C_2}{C_1}=\frac{R_1+R_2+R_3}{R_1}$$

When the resistance R_3 of each of the equal coils of large copper wire is so small in comparison with the other resistances that it may be neglected, we may write

$$\frac{C_2}{C_1}=\frac{R_1+R_2}{R_1}.$$

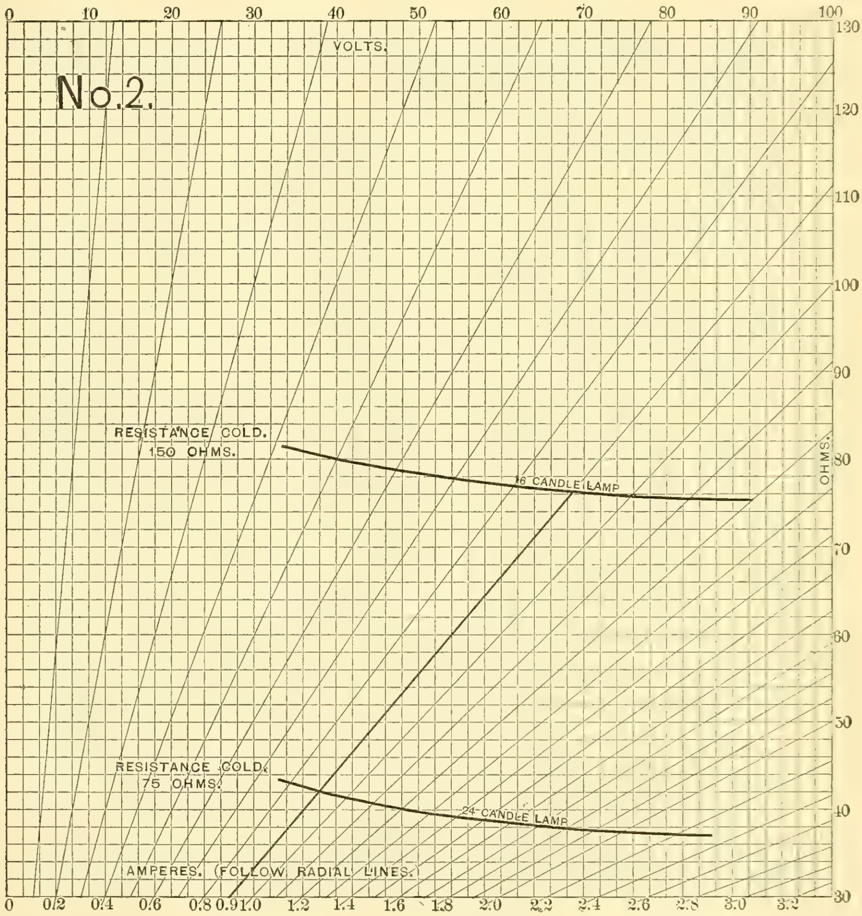
Expressing this equation in words, we say that the current passing through the lamp is to the current passing through the resistance coil R, as the sum of the resistances of the fixed and variable arms of the bridge is to the resistance of the fixed arm.

Having thus found the ratio between the currents in the two branches of the circuit, and knowing also by observation of the ammeter, the value of the total current C, which is the sum of the two portions C_1 and C_2, it is an easy matter to find the absolute value of the current in each branch of the circuit. The electromotive force on the branch *abe* is then computed by multiplying the resistance of that branch by the current passing through it, and this gives us the electromotive force between the terminals of the lamp, after deducting the trifling amount necessary to overcome the resistance of the wire in the branch *ade*. The horse power expended in the lamp is then found by multiplying together the

values of the electromotive force and the current, and dividing the product by 746.

The resistance R_3 of each of the equal coils *be* and *de* was in this case only 0.424 ohm, and the fixed arm of the bridge was generally made 1000 ohms. The value of R_3 was not neglected in the calculations, but as the error that would have been caused by its neglect would be in the fifth decimal place, its use was an unnecessary refinement.

through the coils of the bridge, we may, by adjusting the resistance of the fixed arm, reduce the current to a strength just sufficient to obtain deflections of the galvanometer; third, while the current passes constantly through the lamp, the circuit through the bridge is closed only when the key is depressed. It was found that, with ordinary care, the ratio of two currents could be thus ascertained accurately to four decimal places.



The above method of ascertaining the electromotive force and current of an incandescent lamp possesses several practical advantages over any method in which the lamp itself forms one arm of a Wheatstone's bridge. First, no special apparatus is required; second, instead of passing the entire current constantly

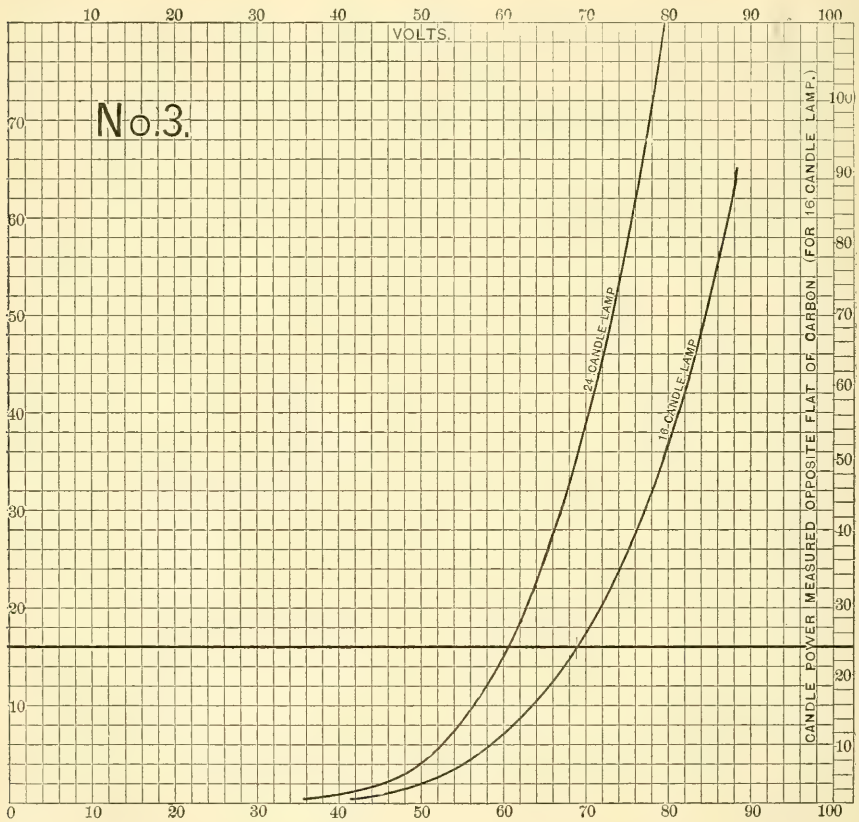
PRECAUTIONS OBSERVED.

The accuracy of this method of comparing currents evidently depends upon the exact equality of the resistances of the two coils *be* and *de*. They consisted of number six copper wire, covered with paraffined cotton braid. Such wire will carry fifty amperes without warming per-

ceptibly, and as the currents used in these experiments rarely exceeded two amperes, there was no danger from unequal heating of the two coils. Before beginning the tests, these coils were adjusted to equality by means of the Wheatstone's bridge, the final adjustment being made by a sliding contact resting on the wire, with the galvanometer so sensitive that a variation of $\frac{1}{100}$ of one per cent. was perceptible. Their equality was again tested at the close of the work. To insure that the two coils should always be at the same temperature, they were wound on a frame into a single loose coil.

It was also important that the resistance of the coil R should not be altered by the passage of the current. This coil consisted of about 200 ohms of number eighteen German silver wire. It was wound with silk, and hung loosely over a frame, so that the air could circulate freely through it. The current traversing it never exceeded one ampere, and was generally much less, so that it did not warm perceptibly. This coil was also arranged so that it could be instantly taken out of the circuit and connected with the bridge, and its resistance measured at intervals during the progress of a test. It was found that the error due to the heating of this coil never exceeded $\frac{1}{10}$ of one per cent.

This part of the work was carried on at times by two observers, one of whom observed the ammeter and the bridge, while the other took simultaneous observations with the photometer. At other times the writer alone took all the observations, reading first the ammeter and the bridge, then the photometer, and then, to insure that no change had occurred, again reading the ammeter and bridge.



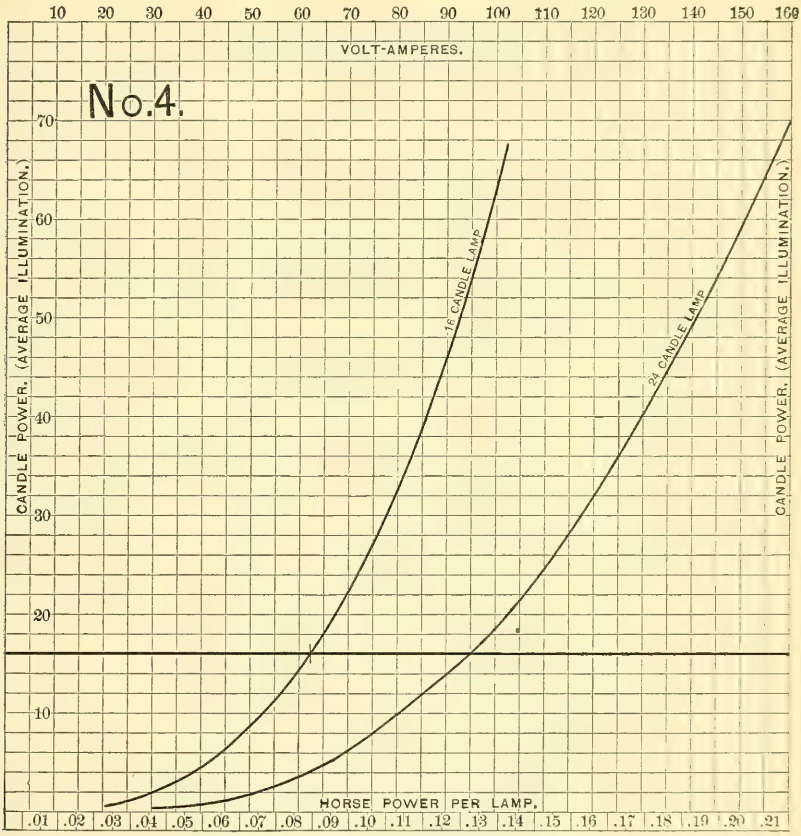
THE PHOTOMETRIC TESTS.

In these, and all the observations with

the photometer, five or more readings were taken at every point, and their mean used as the true reading. After considerable practice, these photometric readings could be made quite exactly.

In these measurements, a Carcel lamp, burning colza oil, was used as a standard of light, the employment of a candle for this kind of work being impracticable for various reasons. In order to obtain as steady a light as possible from the Carcel, the top and bottom of the flame were diaphragmed off, and only the middle, or least variable portion, was used as a standard. The width of the aperture was adjusted so that the lamp gave an average of about ten candle power.

Though the light of the Carcel lamp was not subject to sudden fluctuations, like that of a candle, and would remain practically constant during a single series of observations, there was nevertheless a slow variation, due to the gradual crusting over of the wick, and to differences in the temperature of the room at different times. The error from these causes was eliminated, as far as concerned the variation in the candle power of each individual lamp, by taking always a series of observations in which the candle power was gradually increased, and immediately following it by another series in reverse order in which the candle power was decreased to the starting point.



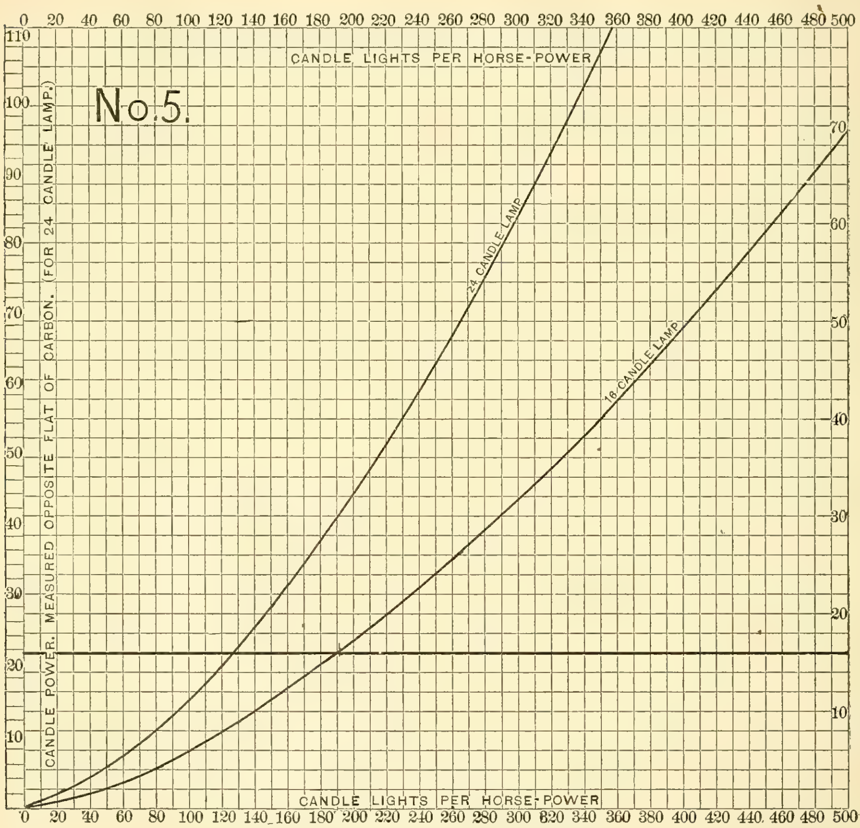
The results of these observations, then, while showing accurately the relative changes in the candle power of each lamp for given variations in electromotive force and current, could not be implicitly relied upon for comparisons between different lamps.

Accordingly, while the electrical quantities were here obtained in absolute

measure, it was not attempted in this part of the work, to measure candle power with absolute accuracy, but merely to obtain the data from which a curve could be constructed for each lamp showing on some arbitrary scale the *variation* in candle power with different electromotive forces.

The remaining problem was to reduce all these curves to the same absolute scale. One of the lamps was next run for some eight hours at about its rated candle power, and very carefully compared with a standard candle, measurements being constantly taken of the candle power, current, and electromotive force. The candle was hung on the arm of a balance made for the purpose, and the time required for the consumption of each twenty grains was noted, and the proper corrections made. Several standard candles were used, all of which were obtained from Tufts Brothers, Boston, and burned very nearly 120 grains per hour.

The average of the above observations gives us the absolute candle power and electromotive force for a single point on the curve of this individual lamp. To get the entire curve into absolute measure it is simply necessary to change the scale of the diagram to conform to this measurement. Having done this, we have two correct curves for a single lamp, in which abscissas represent volts, and ordinates represent, in the one curve, amperes of current, and in the other, candle powers.



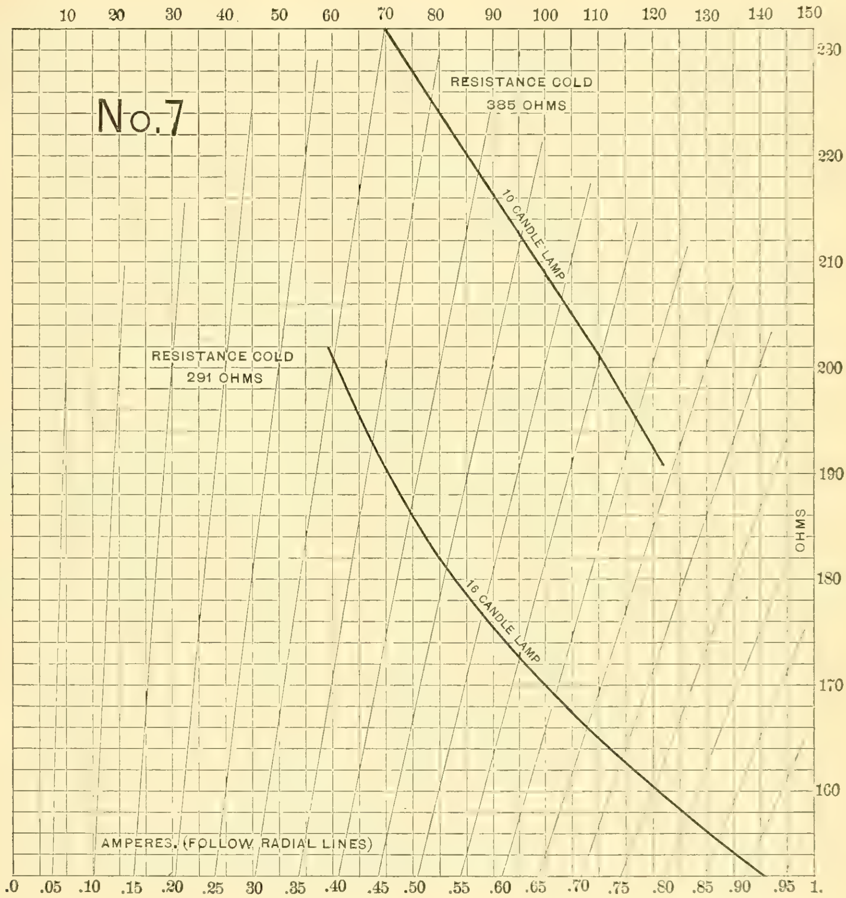
DIRECT COMPARISON OF EFFICIENCIES.

The remaining curves were next reduced to the same absolute scale by a system of direct comparisons of the lamps at opposite ends of the photometer.

The method consisted in placing at one end of the photometer bar, a lamp whose curves of candle power and current had been already obtained in absolute measure, and at the other end the lamp whose curve was to be reduced to that standard. The lamps were then run at their rated candle power, and their relative brilliancy ascertained by the photometer.

If the two lamps were of the same kind, or required about the same current strength to bring them to their normal brightness, they were connected in series, and the strength of the current through both ascertained by the ammeter. In other cases they were placed in multiple arc, adjusted to the proper relative candle power by a variable resistance in one branch of the circuit, and the current through each branch measured by the bridge method.

By thus obtaining accurately the ratio of the currents flowing through two different forms of incandescent lamps, while they are running at a given relative brilliancy, and knowing, from our previous experiments the ratio of the resistances of the two lamps with these given currents, the *relative efficiencies* of the lamps are ascertained independently of the absolute measurements.



Having obtained in this way the relative candle power of two lamps at two given points on their respective curves, it is simply a matter of altering the scale of one diagram to bring both to the same absolute standard.

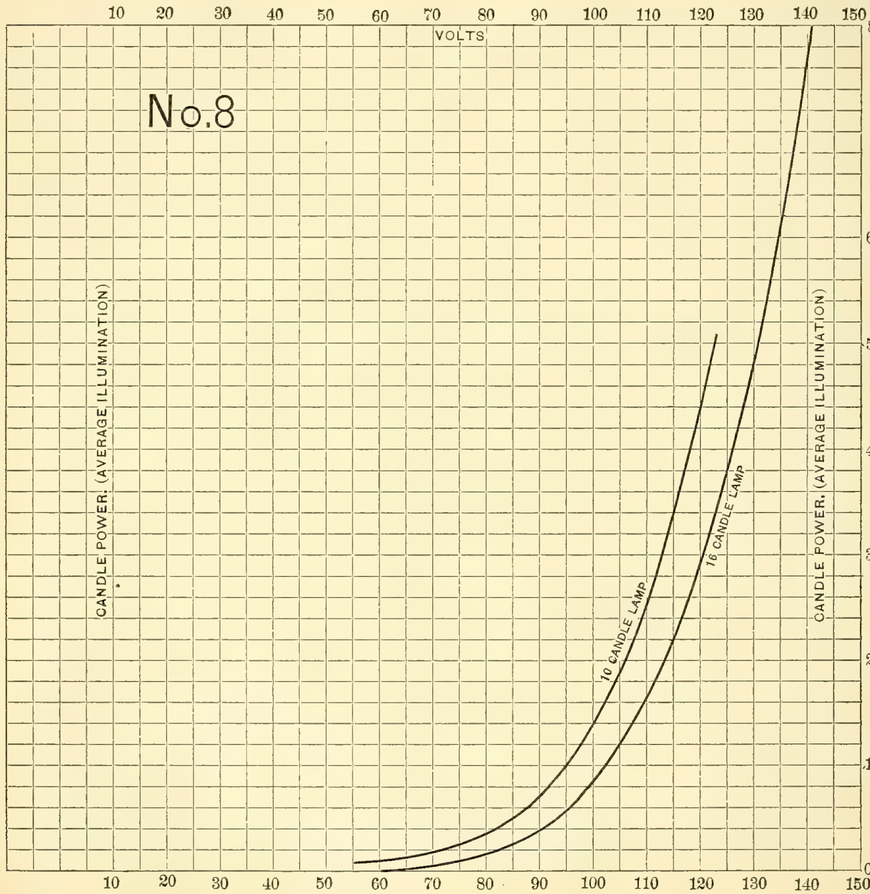
The great advantage of this comparative method lies in the fact that as but

one absolute determination of candle power is made, this one can occupy a good deal of time, and be made with great care; and further, that as the *relative* efficiencies of the different lamps are ascertained by comparing the light of one lamp directly with that of another, while at the same time the relative values of the currents and electromotive forces are obtained by direct comparison, any errors that may be made in the absolute measurements will affect all the lamps alike, and *cannot alter the relative efficiencies.*

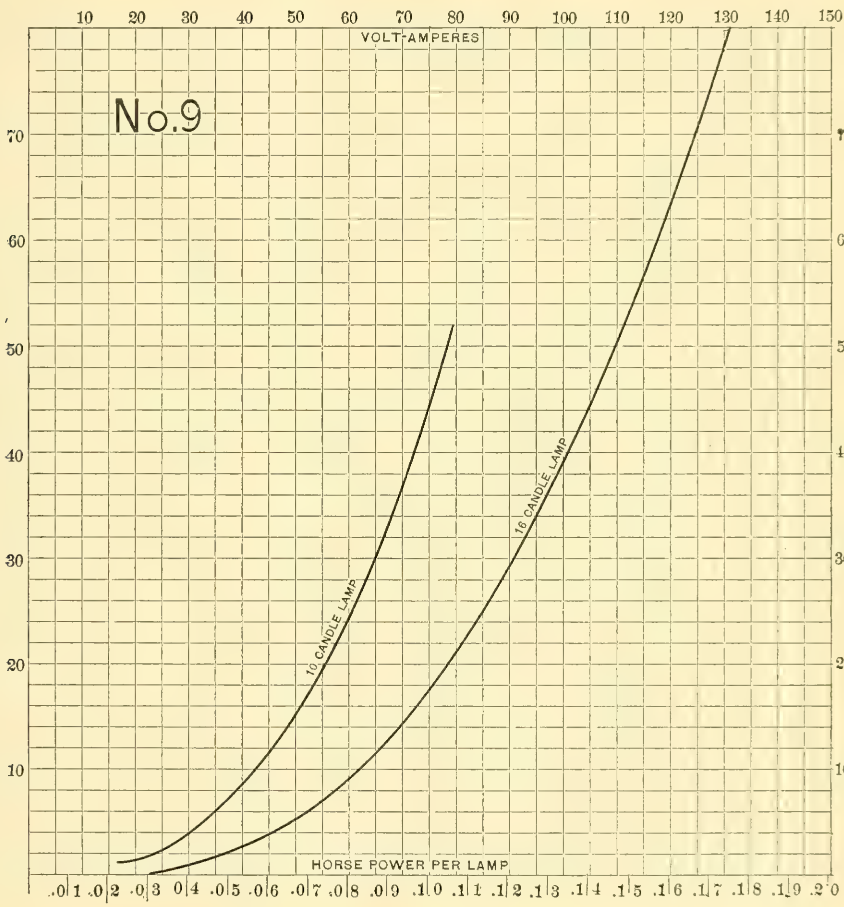
It is of course impossible in a brief memoir to describe all the details and precautions against error employed in work which extended over a period of about two months. Therefore, having given a sufficient account of the methods used to enable one to form a fair idea of their reliability, we now pass on to consider

THE RESULTS.

The first result of the experiments just described was a series of curves, showing, for each individual lamp tested, the value of the current strength in amperes, and the candle power, for a range of electromotive forces, from the point where the carbon is barely incandescent, to a point where the lamp is giving four or five times its normal candle power. These results were carefully averaged for each class of lamps. The method of averaging was to take lamps of the same kind,—not at the same candle power, but at the same electromotive force, as they are intended to be run in practice,—and find,

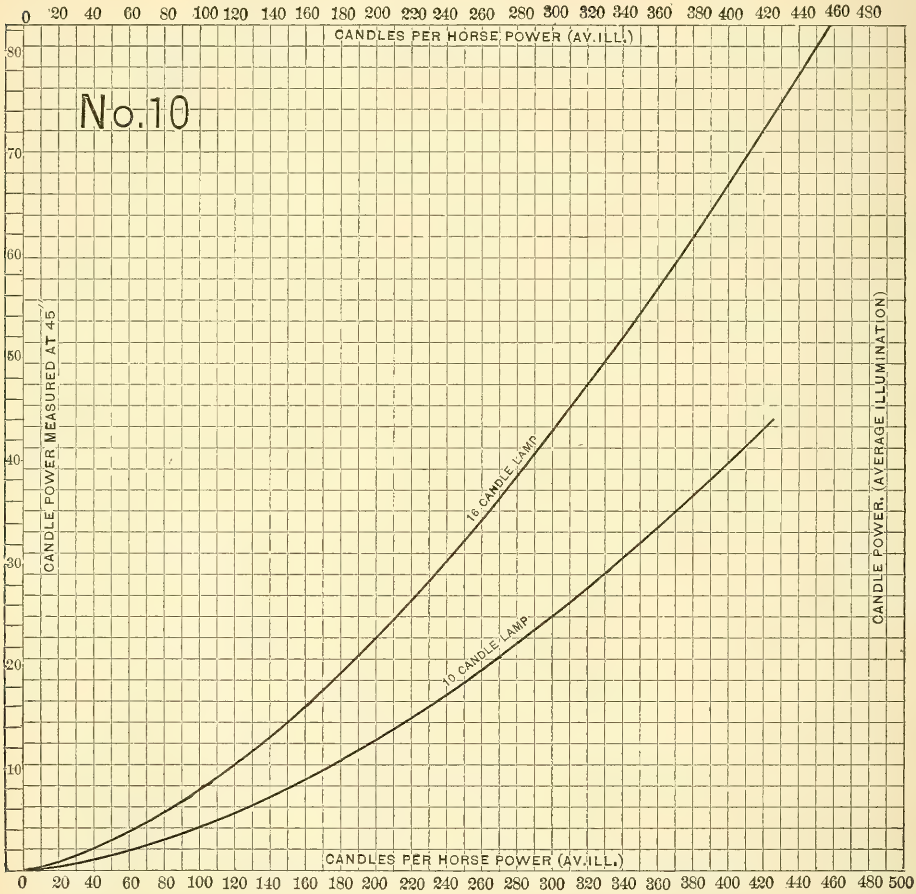


from the curves for the separate lamps, the values of the candle powers and amperes at intervals of five volts. Then the average of these values was taken at each point; the average resistances being computed by dividing the number of volts by the average number of the amperes. This gives to all the quantities the same mean values which they would have in an actual case, where the lamps are run in multiple arc.



The average results have been represented graphically, and are shown by the diagrams hereto annexed. The curves of equal illumination have already been referred to. The next curves plotted were intended to show, for each class of lamps, the relation between the electromotive force, current, and resistance. Diagram No. 2 shows these curves for the Maxim lamps, and No. 7 shows the same thing for the Edison lamps. In these diagrams electromotive force in volts is laid off on the horizontal scale at the top, and the curve for each lamp is so constructed that the height of any point on it represents on the vertical scale at the right. the resistance of the lamp in ohms, under the corresponding electromotive force. It is also desirable to show the current which will flow through the lamp under a given electromotive force, and also the resistance of the carbon when a given current is passing through it. We have, then, to express the relations of three pairs of quantities. This might be done by three separate diagrams; but as the current is always equal to the electromotive force divided by the resistance, it may be represented, for any point on

the curve, by the tangent of the angle included between the vertical axis of co-ordinates, and a line from the origin to the given point. Therefore, by drawing radial lines through the origin, (which is in this case outside the limits of the diagram,) we are enabled to lay off amperes of current on a scale of equal parts at the bottom, thus making the same curve express the relation between three variables.



To find the current for any point on either of the curves, it is necessary only to follow a radial line from the given point down to the scale at the base of the diagram; or, starting with a certain current, follow the radial lines up to the corresponding point on the proper curve; then to find the resistance of the lamp with the given current, follow a horizontal line from that point to the scale at the right; or to find the electromotive force, follow a vertical line through the same point to the scale at the top. In short, given any one of the three quantities,—electromotive force, current, or resistance,—the other two may be found at once from a single curve. This device for expressing graphically the triple relation between the principal electrical quantities the writer believes to be new, and it is presented as one that will be frequently found convenient.

In diagrams No. 3 and No. 8 electromotive force is again represented on the horizontal scales at the top and bottom, and the height of any point on either curve shows on the vertical scales at each side the number of candle powers of light

which the lamp will give with the indicated electromotive force.

The resistance of a lamp is found to fall quite rapidly as the electromotive force is increased, until the carbon becomes incandescent, when the change goes on more slowly, the resistance of a lamp when giving its light being rather more than half its resistance when cold. As will be seen from diagrams No. 3 and No. 8, the candle power increases slowly at first, but afterwards with increasing rapidity, until, if the electromotive force is carried above a certain point, the carbon filament is broken.

In diagrams No. 4 and No. 9, the horizontal distance of any point on either curve to the right of the origin represents the power consumed in the lamp, expressed in horse power on the scale at the bottom, and in volt-amperes on the scale at the top. Candle power is again laid off on a vertical scale. These curves show clearly what has before been stated, *i.e.* that a certain amount of power must be expended in a lamp before we begin to get any light; and that the brilliancy of the light expressed in candle powers then rises more and more rapidly as the energy expended is increased.

In diagrams No. 5 and No. 10 the vertical height of any point of either curve corresponds as before to the candle power of the lamp, and the distance of the same point to the right of the origin measures, on the horizontal scales at the top and bottom, the number of candle lights per horse power which lamps of this class will furnish when running at the indicated candle power. These curves show us how rapidly the efficiency of the lamps increases as the candle power is raised.

In diagrams No. 3 and No. 5 the vertical scale at one side indicates the apparent candle power as measured opposite the face of the carbon, and that at the other side the average or true candle power. It will be observed that the Maxim 16 candle lamp, at its normal candle power (indicated on the diagram by the heavy horizontal line), gives a light equal to 22 candles opposite the face of the carbon, and that the average illumination is about 73 per cent. of the face measurement.

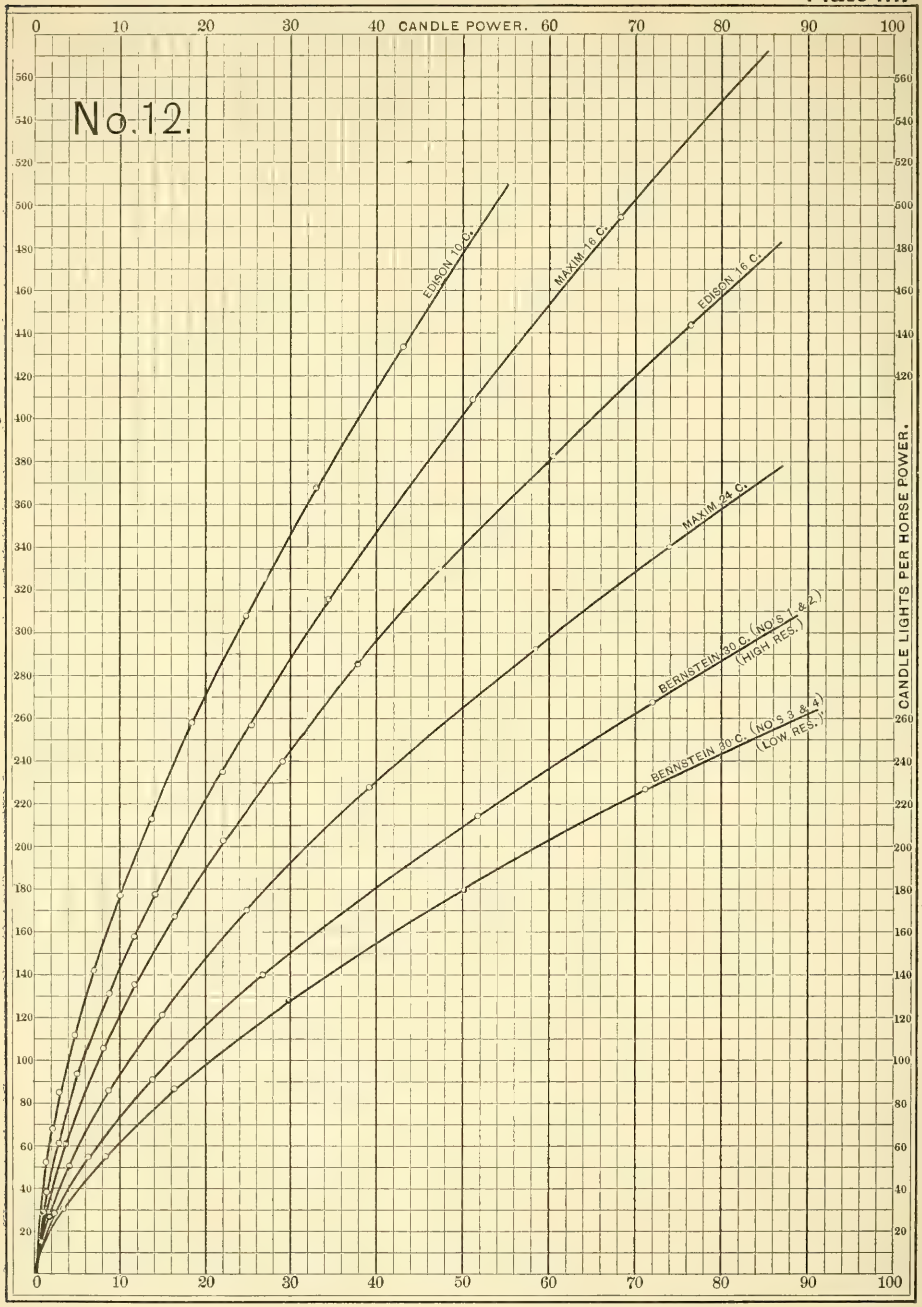
The curves in all the diagrams are drawn exactly through the plotted points; the slight irregularities apparent in the curves for the separate lamps being almost wholly eliminated in the average.

In Fig. 12 the curves representing the change in efficiency of the various lamps at different candle powers are shown upon a single diagram for the purpose of comparison. Here candle power is laid off on a horizontal scale, and, for each class of lamps, the height of any point of the curve indicates on the vertical scale the number of candle lights per horse power which the lamps will give when running at the corresponding candle power. It is noticeable that all the curves have the same characteristics, viz., that the efficiency at first rises very rapidly with increase of candle power, and that afterwards, while the change goes on more and more slowly, the rate of increase in efficiency becomes at the same time more nearly uniform, or, in other words, the curve approaches to a straight line. This would indicate, that however high the temperature of a carbon filament may be raised, raising it higher will still increase its efficiency as a light giver.

It must not be inferred, because the curve of any lamp is above the rest, that this lamp is absolutely more efficient than the others; for, as already pointed out, when a lamp designed to give 10 candle power is run at, for example, 16 candle power, its efficiency becomes higher than its normal value; whereas, if a 24 candle lamp is run at 16 candle power, its efficiency falls below its normal value. Consequently, when lamps rated at different candle powers are compared at the same candle power, the lamp with the lower rating has an advantage. The only way to arrive at a fair comparison is to take the efficiency of each lamp at a point on its curve which corresponds to the rated candle power. Comparing the lamps in this way, we find that the Maxim 16 candle lamp stands highest, and the Edison 10 candle lamp next.

It should be noticed that the Edison 16 candle lamps furnished for this test were not of the same grade as those in general use for isolated lighting. The latter may be run in parallel circuit with the 10 candle lamps, each giving its own proper candle power; whereas the Edison 16 candle lamps on which these tests were made would give only about 6

Plate III.



candle power on the same circuit with the 10 candle lamps, when the latter were at their normal brightness. By refering to diagram No. 8, it will be apparent that at the same electromotive force the 16 candle lamps gave only about two thirds as much light as the 10 candle lamps. This peculiarity was due to the high resistance of the 16 candle lamps, which, as will be seen from the

table of resistances previously given, averaged about 291 ohms when cold. Measurements afterwards made by the writer upon ten 16 candle lamps, collected from various plants of the Edison Company throughout New England, showed the following results:

RESISTANCE COLD.

Lamp No. 1	162 Ohms.
" " 2	176 "
" " 3	163 "
" " 4	186 "
" " 5	177 "
" " 6	175 "
" " 7	189 "
" " 8	186 "
" " 9	212 "
" " 10	197 "
Average resistance	182.3 Ohms.

These lamps averaged 16 candle power at 95 volts, the same electromotive force required to bring the 10 candle lamps to their normal brightness, and were therefore evidently the grade of lamps intended to run on the same circuit with the latter. They were not obtained in time to make a complete test at all candle powers, but measurements were made at the rated candle power, which gave the following average results.

EDISON LAMPS AT 16 CANDLE POWER.

Electromotive force	95. volts.
Current strength	0.92 ampere.
Resistance	103.3 ohms.
Volt-amperes	87.4
Candle lights per horse power	136.6
Lamps per horse power	8 54

The following are the figures for the Maxim 16 candle lamps.

MAXIM LAMPS AT 16 CANDLE POWER.

Electromotive force	68.9 volts
Current strength	0.9 ampere.
Resistance	76.5 ohms.
Volt-amperes	62.2
Candle lights per horse power	192.
Lamps per horse power	12.

The results of these experiments indicate that the essential factor in the efficiency of an incandescent lamp is not high resistance, but high incandescence. The Maxim lamps, which displayed the highest efficiency, gave a slightly whiter light than the others, showing that the carbons were heated to a higher temperature; though their resistance was lower than that of the Edison lamps. The fact that a low resistance filament is usually coarser than one of high resistance would tend to make it endure equally well at a higher temperature.

TESTS OF RUTLAND AND WASHINGTON COUNTY SLATES.

By J. FRANCIS WILLIAMS, C. E., B. S.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE tests given in the following tables were made June 7th and 9th, 1884, in the mechanical laboratory of the Rensselair Polytechnic Institute, Troy, N. Y., on a 50,000 pound testing machine made by Tinius Olsen.

The purple and green specimens were from Fair Haven, Vt., and the red from Granville, N. Y. They were cut and smoothed by the Fair Haven Marble and Marbleized Slate Co., of Fair Haven, Vt.

Before making each test, the piece under consideration was carefully measured on a micrometer measuring apparatus, and the size in each direction recorded. The results were recorded as pressures per sq. inch. The pieces experimented upon did not differ more than 2 or 3 hundredths of an inch in a normal section.

The experiments marked "compression" were made upon blocks about one square inch in section and $1\frac{1}{2}$ inches in height. In the cases marked "wood" blocks of wood $1\frac{1}{2}\times1\frac{1}{2}\times1\frac{1}{4}$ inches were used as cushions, one above and one below the specimen, they were of soft wood and were so placed that the grain did not run in the same direction in the two pieces, and thus there was no tendency of the blocks to become crooked in the machine.

With those marked "paste-board," book-binder's board was used in pieces of $1\frac{1}{2}''\times1\frac{1}{2}''\times\frac{3}{16}''$. This is closer in texture and gave results about one-fifth larger

TESTS.

Substances used as Cushions and Methods of the Tests.	Purple.		Red.		Green.	
	Weight ℔ sq. in.	Remarks.	Weight ℔ sq. in.	Remarks.	Weight ℔ sq. in.	Remarks.
Compressive wood.....	17330	1 seam	14390	crack 11220	13760	
" "	22140		13535	1 seam	12520	2 seams
" "	20540	crack 16010	14580			
" "	18700	2 seams				
" "	18170	crack 17370 1 seam				
" paste-board.	24760		14590	crack'd at 12440 1 seam	17420	2 seams
" "			18160		17930	1 seam
" "			21310		16840	1 "
" "			18380		18060	crushed at op. angles
" no cushion	12640		10190		8040	2 seams
" elastic limit	9860		4850		5150	
" no cushion.	13430					
" elastic limit	10480					
" no cushion.	15530	small seam				
" elastic limit	10440					
" on side-wood.	15195	Section 1"×1½" 2 seams	24030	Section 1"×1½"	17760	crack 16700 1 seam

TESTS—Continued.

Method of Test and Length of Beam.	Purple.		Red.		Green.	
	Weight. Center Load.	Number and Remarks.	Weight. Center Load.	Number and Remarks.	Weight. Center Load.	Number and Remarks.
Bending 6 in. span.........	1150	(1.)	775	(1.) 1 seam	950	(1.)
" "	1025	(2.) split along	1100	(2.)	775	(2.) small seam
" "	1425	(3.)	450	(3.) bad seam	1025	(3.)
" 3 in. span.........	2400	(4.)	1875	(2.) no seam	1825	(2.)
" "			2250	(2.)	2400	(3.)
" "			1000	(1.) 1 seam		
Compression 10 in. column.	20000		17730		16020	

RESULTS OF THE ABOVE TESTS.

Compression, wood........	19376	No. of specs. 5.	14170	No. of specs. 3.	13140	No. of specs. 3.
" paste-board...	24760	" 1.	18110	" 4.	17560	" 4.
" no cushions..	13860	" 3.	10190	" 1.	8040	" 1.
" elastic limit..	10260	" 3.	4850	" 1.	5150	" 1.
Bending 6in. span.........	1200	" 3.	770	" 3.	910	" 3.
" 3in. "	2400	" 1.	1710	" 3.	2110	" 2.
Compression, long columns.	20000	" 1.	17730	" 1.	16020	" 1.
" on side......	15195	" 1.	24030	" 1.	17760	" 1.

than the wood, and I should recommend that all experiments with stone be made with such cushions.

In the preceding cases the blocks have all been placed so that the cleavage planes of the slate are horizontal—perpendicular to direction of stress—but in the case marked "on side" they were

placed in a vertical position and the specimen then had an area of section of $1\frac{1}{2}$ square inches. This was not reduced to inch square.

Those tests marked "no cushion" were made on specimens which had particularly smooth and parallel upper and lower surfaces, and the elastic limit was carefully observed. The U. R. in this case of course was low, owing to the unequal distribution of pressure over the surfaces.

The beams tested were an inch in section and 10 inches long. The supports were placed 6 inches apart and were covered with paste-board so as not to cut the extreme fibers of the beam. The point in the center, by which the pressure was applied was also covered with pasteboard.

After the beam was broken with a six inch span the two portions were in some cases broken again as beams of a three inch span. This is indicated by the numbers placed in brackets after the breaking weight. The first three being numbered consecutively, and those which are used a second time being designated by the same numbers that they had when first broken. These, of course, were broken with their cleavage planes horizontal.

The last specimen was broken as a long column with the cleavage planes vertical. It stood more than the small blocks, crushed and broke with considerable violence.

A NOTE ON THE LONG COLUMN QUESTION.

By WM. H. BURR.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

It is not a matter of surprise that Prof. Robinson should take exception to my criticism of his long column formula, or that Mr. Weston should desire to give to the immense amount of labor, involved in the computation of his tables, a character other than that of wreckage. After the lapse of so much time, one would suppose that some new point of demonstration would have been developed, or, at least, that something tangible would have been said. It is also a little remarkable that Prof. Robinson makes no attempt to strengthen the points in his analysis which I attacked. Hence, it may be supposed that he considers them hopelessly overthrown—one point, at least, on which we agree. I had also hoped that he would render a lucid explanation of the fact that his "rational" formula gives a curve convex upward within the limits, for which experiments give a curve *concave* upward. (See Magazine for Nov. 1883.) But as he omits the explanation and stoutly maintains that his formula is certainly, truly, and incontestably "rational," we are left to infer that the results of the tests are unquestionably irrational, and that the upward concavity of the curve is simply and only an evidence of the original and "total depravity of inanimate things" which has from time to time been hitherto observed under proper circumstances.

But in order to come to a more detailed consideration of Prof. Robinson's last article, his analytical positions will first be examined while subsequent attention will be applied to experimental matters.

In the first place he proposes to give a new demonstration of his formula without the slightest reference to Euler's, by considering the neutral curve of the column a sinusoid!!!

As a result, in the April (1884) number of this Magazine, page 184, he finds the following value of the radius of curvation:

$$\rho_1 = \frac{l^2}{\pi^2 y_1} \quad . \quad . \quad . \quad (d).$$

Eq. (d), it is to be particularly observed, is supposed to be very different from Euler's formula.

Now, in a little book published in 1882, "Strength of Wrought Iron Bridge Members, by S. W. Robinson, C. E.," "an authority which my opponent will doubtless accept as sound," on page 84 is found Euler's formula:

$$\frac{T}{EI_1} = \frac{\pi^2}{l_1} \quad . \quad . \quad . \quad (1);$$

and on page 93, the usual equation of the common theory of flexure;

$$\frac{\mathrm{EI}}{\rho}=\mathrm{T}y_1 \quad . \quad . \quad . \quad (2)$$

The subscript 1 has been introduced in eqs. (1) and (2), in order to make the notation uniform with eq. (d).

If the value of ρ_1 be taken from eq. (2) and inserted in eq. (d), then will result:

$$\frac{\mathrm{T}}{\mathrm{EI}_1}=\frac{\pi^2}{l^2};$$

which is Euler's formula, and identical with eq. (d). In reality, therefore, Prof. Robinson has given in his sinusoidal method simply "a new toot on an old horn." Can it be possible that he was ignorant of the fact, that the use of the sinusoid simply meant the use of the common theory of flexure in another *form*, only, than Euler's formula?

Since his "new demonstration" is thus seen to involve Euler's expression for the resistance of a long column, another "new demonstration" from the same source is now in order, and it will be awaited with interest.

After having vainly endeavored to shut Euler's formula out of view, by heaping over it considerable unnecessary sinusoidal analysis, Prof. Robinson then subjects the "classical" formula

$$\mathrm{M}=\frac{\mathrm{RI}}{d_1}=\frac{\mathrm{RA}k^2}{d_1}; \quad . \quad . \quad (3)$$

to some most unhandsome treatment. We are told, on page 285, that R is the modulus of rupture for bending and that, hence, a beam will sustain the least load in that plane in which d_1 is greatest. Now I am aware that Prof. Robinson is not alone in that impression, though it is most erroneous. As a matter of fact, eq (3) is an equation deduced in the mathematical theory of elasticity in solid bodies, and has no "rational" connection whatever with the *failure* of beams or material. It is based upon the hypothesis of perfect elasticity, and is merely another form of $\frac{\mathrm{EI}}{\rho}$, $\mathrm{R}\div d_1$ representing $\mathrm{E}\div\rho$ or the intensity of stress at unit's distance from the neutral surface.

When R is given the signification of the "modulus of resistance" and determined by experiments on the failure of beams, it ceases to have any rational or analytical meaning, though it is thereby made of inestimable value to engineering practice. Prof. Robinson handles this part of the matter with that freshness and *naiveté* which is so characteristic of unconcious lack of knowledge, and it is useless to carry this part of the discussion any farther until he informs himself more thoroughly on some of the more fundamental portions of the theory of flexure. I would refer him to Clebsch's "Die Theorie der Elasticität Festr Körper," where he will find an admirable treatment of the subject.

Prof. Robinson's reference to the Watertown tests of Phœnix columns scarcely agrees with the facts as given in the copy of the Trans. of the Am. Soc. C. E. now before me. As nearly as can be learned from that publication, Nos. 1, 4, 5, 7, 8, 12, 13, 16 failed in the plane of two flanges, while Nos. 2, 6, 9, 10, 11, 14, 15, 17 gave way in the direction of the barrel between the flanges—an equal number in each direction—while the remaining 6 cases are doubtful. These results therefore show that a Phœnix column is equally liable to fail in any direction—a conclusion which has been verified by other experiments at Phœnixville as well as by a proper consideration of the theory. Prof. Robinson's error lies in considering R as separate from $1\div d_1$; he should consider $\mathrm{R}\div d_1$ as a single quantity.

The old paradox of the triangular beam may be properly used by a youthful instructor to impress his first class with the mysteries of the resistance of materials, but it is good for nothing else. Such a beam is just as strong as, but no stronger than, the trapezoidal one. Its fibers begin to rupture at an earlier stage of loading, but the ultimate load held, is exactly the same in both cases.

We now come to the experimental portion of the April paper, and we find in looking over Prof. Robinson's application of his "rational" formula that he causes T to vary from 40,000 to 45,000, and E from about 23,000,000 to 31,000,000, in order to get a satisfactory agreement between his results and those of experiment. Now this is precisely what is done in all empirical formulas, and its necessity might be a matter of surprise in the present instance if I had not shown in

my first paper that his formula is simply and only a mongrel form of Gordon's; hence he is obliged to doctor it in passing from one form of section to another, in order to get a satisfactory approach to agreement with the results of tests.

But there are some features of his comparison of Gordon's formula with his own which ought not to be overlooked.

In the first place, while he gives to the empirical factors in his own formula such values as are needed to reach the closest agreement to experiment, he takes an antiquated form of Gordon's formula with empirical quantities which belong to a solid rectangular section in iron produced forty years ago, or more, and applies it, without change, to all forms of sections. Such a suspicious procedure can only result from either ignorance or design, and I refrain from comment.

But even with such aid the mean discrepancies of his own formula are less than those of Gordon's by only 400 or 500 pounds at most,—an insignificant amount for such a matter. In fact a truthful presentation of the table at top of page 288 of the April No. would probably turn the balance in favor of Gordon's formula. In that table there is a column headed "New Formula," with the evident design of conveying the impression that the results of that column come from his own formula, though an incidental explanation is given in the text. The upper five values of the column in question (nearly one-third of the whole) are the results of computation by Euler's formula, and *not* by Robinson's. To properly name such an action under the present circumstances would carry me beyond the limits of propriety of such a discussion, and I simply give the upper part of the table as it ought to have appeared.

$l \div k$.	Experiment.	New Formula.	Rankine's or Gordon's Form.
643	2410	5130	2885
540	3380	6140	3956
414	4280	8050	6250
400	5630	8350	6604
311	9600	10800	9921
300	9750	11200	10290

His reason, he says, for giving t the remarkably high value of 45,000 is that the iron was "solid," "flat" and "English"!! Such a grade of metal must truly possess unusual characteristics.

Reviewing the whole field, then, it appears that by dint of fitting different empirical factors to Prof. Robinson's "rational" formula, for different forms of section, results may be obtained which, on the whole, are little or no better than those arising from an unfair and improper application of an antiquated form of Gordon's formula.

In regard to Mr. Weston's paper, little need now be said. His analytical attempt to fix the safe limit of deflection is simply a futile effort to distort an equality into an inequality, and is precisely the same feature which I attacked in Prof. Robinson's original paper; and as he has since made no attempt to repair the damage, it is scarcely worth while to repeat the criticism.

Mr. Weston's appeal to the theory of flexure comes within the scope of my observations on Prof. Robinson's attempts in the same direction; and his sublime faith in the innate superiority of the new formula to the results of experiment, makes it rather useless to attempt to bring him down to a consideration of a set of experimental results. Since, in fact, he thinks (pp. 401 and 402 of May No.) that "the new formula cannot, with justice, be compared with experimental results obtained in the usual method of breaking columns," and that "it is a question whether practice would really desire the new formulas to agree with the results of experiments for ultimate strength;" also, that the "irregular agreement of experimental and computed results, when t is given a value approximately equal to the ultimate resistance, does not prove or disprove the new formula, but, on the other hand, rather weakens the confidence in the usefulness of experimental results for ultimate strength;" it becomes a serious question whether he is not only using rather a "free lance" against engineering column practice, but also taking Prof. Robinson both in flank and rear for making such desperate and questionable efforts to get even an approximate agreement between the results of tests and his own formula. I leave them to settle this question between themselves and take my adieu of the discussion.

THE EVAPORATIVE POWER OF ANTHRACITE COAL IN TESTS OF STEAM BOILERS.

By WILLIAM KENT, M. E.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

That portion of Mr. R. H. Buel's paper on the Compound Steam Engine, etc., which relates to the Steam Boiler (VAN NOSTRAND'S ENGINEERING MAGAZINE for June) contains so many statements which are at variance with the generally received opinions concerning boiler performance and economy, that it should not be allowed to become a portion of American engineering literature unchallenged. It would be difficult to discuss completely such an elaborate paper, crowded as it is with tables of figures, without occupying more space than is taken by the paper itself, but a few of the statements to which exception may be taken may be discussed briefly.

Mr. Buel states, in reference to the summary of the experiments of Messrs. Kestner and Meunier: "There are no American coals in this table, but as the best anthracite coal of the United States contains more fixed carbon than any specimen of Table XI., it is reasonable to suppose that it is at least equal in heating power to the best European coal tested by Messrs. Kestner and Meunier."

It is unreasonable to make the supposition, 1st, because there are no records anywhere published of accurate determination of the total calorific value of American anthracite by which to support the supposition. 2d, because in Kestner and Meunier's table, the Groufcheski anthracite, which contains the largest percentage of fixed carbon of any of the coals, has the lowest evaporative power but one (lignites excepted), and hence by analogy we would infer that the American anthracites having higher percentages of fixed carbon, would have lower evaporative power (per pound of combustible). 3d, because, as stated by Mr. Buel in his quotation from Gruner, "the heat of combustion of a body, simple or compound, is in general greater in proportion as its molecular condensation is less advanced," and "the heat of combustion like the specific heat varies with the density." Moreover, as shown by M. Gruner, since the diamond gives by experiment only 13,986 units, graphite 14,035, gas retort charcoal 14,485, the less dense wood charcoal 14,544, and gaseous carbon theoretically 20,186 heat units, the calorific power increasing as compactness of structure diminishes, it would be reasonable to suppose that anthracite, in which the carbon is probably as compact as in gas retort charcoal, would have a similar heating value, or about 14,500 heat units.

The writer has always in his experience in testing boilers, or in calculating the results of tests, assumed the calorific value of the combustible portion of anthracite coal to be 14,500 heat units, equivalent to an evaporation of 15 lbs. of water from and at 212°; and he has thus far seen no reason to believe that more than 80 per cent. of this heating power can be utilized under ordinary working conditions in any boiler in which the products of combustion are allowed to escape at a temperature above 350° or 400°.

Mr. Buel gives a number of results of experiments "generally regarded as being amongst the most reliable that have ever been made, all of which must be repudiated by those who believe that the maximum heating effect attainable from the combustible in the best varieties of American anthracite is 14,544 thermal units per lb., and that the average amount of air supplied to furnaces consuming American anthracite is from 25 to 30 lbs. per lb. of coal."

In the absence of any direct and conclusive evidence to the contrary, the reasons given above are sufficient for believing that the heating value of the combustible in the best American anthracite is not more than 14,544 thermal units. And any test of a steam boiler (made as ordinary boiler tests are made, without either measuring the quantity of air supply, or analyzing the coal or the products of combustion, or making direct

test of the heat lost by radiation) which shows a result which would require the heating value of anthracite to be greater than 14,544 units, must be repudiated on that ground alone, if there were no other, notwithstanding the weight of authority which is presumably due to the experiments of Isherwood, or any other engineer "generally regarded as being among the most reliable."

As to the "average amount of air supplied to furnaces consuming American anthracite" being from 25 to 30 lbs. per lb. of coal, perhaps there are not enough data in existence from which to form such an average. In the six anthracite tests by Johnson in Mr. Buel's Table XII., the amount of air supplied ranges from 18.4 to 47.9 lbs., the average being 26 lbs. In the comparative test between Babcock & Wilcox and return tubular boilers, published in VAN NOSTRAND'S MAGAZINE in 1883, Mr. Hoadley found the weight of flue gases per pound of combustible to be respectively 30.71 and 32.10 lbs. Until direct experiment and analysis prove the contrary there seems to be no reason to suppose that the average amount of air supplied in burning a pound of anthracite coal is less than 25 lbs.

Let us suppose that the smallest quantity of air which will burn the carbon of the coal completely is supplied, viz., 12 lbs., or that the flue gases weigh 13 lbs. per lb. of combustible, and that the maximum probable calorific value of the combustible portion of anthracite is 14,544 heat units, and apply these two assumptions to experiments Nos. 5 and 9, Table XXV and No. 1, Table XXII of Mr. Buel's paper.

	Vertical Water-Tube Boiler (Isherwood) Table XXV.		Stead Boiler Table XXII.
	No. 5.	No. 9.	
1. Thermal units per lb. combustible	14,544	14,544	14,544
2. Weight of flue gases per lb. combustible ...	.13	13	13
3. Specific heat of flue gases	.238	.238	.238
4. Temperature of flue gases	322°	600°	621°
5. Temperature of fire-room, say	91	68	68
6. Thermal units lost in flue gases	715	1646	1711
7. Loss by radiation, probably not less than 4 per cent. of 14,544	582	582	582
8. Thermal units available for evaporation	13,247	12,316	12,251
9. Assuming above data: Maximum possible evaporation from and at 212° per lb. combustible..lb.	13.71	12.75	12.68
10. Result of test	14.86	13.32	13.31
11. Maximum possible efficiency per cent.... ...	91.1	84.7	84.2
12. Apparent efficiency obtained in test	98.7	88.4	88.4
13. Apparent efficiency greater than maximum possible per cent	8.4	4.5	6.0
14. If we assume that the flue gases weigh 25 lbs. per lb. of combustible, maximum possible evaporation would be	13.13	11.18	11.05
15. Apparent efficiency greater than maximum possible per cent......	13.2	19.1	20.5

The results shown in this table lead to the conclusion either that the heating value of anthracite coal is greater than 14,544 heat units per lb. of combustible, or that the results of tests showing evaporations of 14.86, 13.32, and 13.31 lbs. are erroneous, the errors being due to neglect of determination of priming, or to possible inaccuracy of measurement.

That the first of these conclusions is untenable has already been shown, that the second is not unwarranted may be shown, not only by the necessity which follows from the exclusion of the first, but by an entirely independent line of argument.

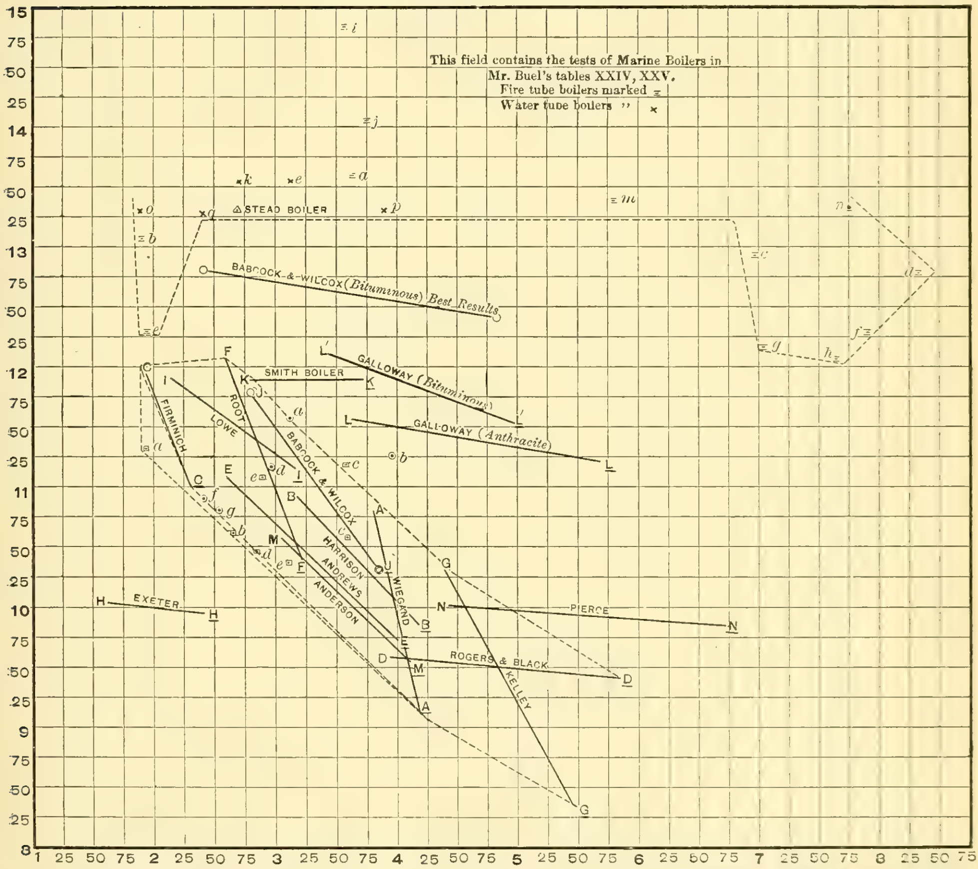
I have selected from Mr. Buel's tables all the figures showing rate of evaporation from and at 212° per square foot of heating surface and per pound of combustible, and arranged them in the table beneath. Column II. contains, in addition to the tests given by Mr. Buel, a few (Nos. 10 to 13) obtained from other sources, and column III. contains some figures from the results of tests at the American Institute Fair, for comparison. I have plotted these figures on cross-section paper, using the lbs. per square foot of heating surface as abscissas, and the lbs. water per lb. of combustible as ordinates, and find that a large majority of all the tests are contained within a somewhat limited field, while a few, including

COMPARATIVE RATES OF EVAPORATION AND ECONOMICAL PERFORMANCE.

I. Centennial Tests. Water evaporated from and at 212°.			II. Babcock & Wilcox Boilers. Water evaporated from and at 212°.			III. Tests at American Institute Fair, 1871. Water evaporated from and at 212°.			IV.—Tests of Cylindrical Tubular Boilers. Table XXIII. Water evaporated from and at 212°.			V.—Water Tube, Fire Tube and Cylinder Boilers. Table XXII. Water evaporated from and at 212°.			VI.—Horizontal Fire Tube Marine Boiler. Table XXIV. Water evaporated from and at 212°.			VII.—Vertical Water Tube Boiler. Table XXV. Water evaporated from and at 212°.			VIII.—Fire Tube and Water Tube Boilers. Table XXVI. Water evaporated from and at 212°.		
Boiler.	Persq.ft. heating surface.	Per lb. combustible.	Number	Pr. sq.ft. heating surface.	Per lb. combustible	Name.	Pr. sq.ft. heating surface.	Per lb. combustible.	Number	Pr. sq.ft. heating surface.	Per lb. combustible.	Number	Pr. sq.ft. heating surface.	Per lb. combustible.	Number	Pr. sq.ft. heating surface.	Per lb. combustible.	Number	Pr. sq.ft. heating surface.	Per lb. combustible.	Number	Pr. sq.ft. heating surface.	Per lb. combustible.
			13	2.44	12.80				2	1.98	12.92							5	3.58	14 86*i*			
L′	3.68	12.125	10	4.81	12.42																		
F	2.59	12.094																6	3 75	14.06*j*			
C	1.93	11.988													3	3.63	13.60*a*	3	2.71	13.55*k*	3	2.71	13.55
K	3.74	11.925										1	2.69	13 31				4	3.13	13.55*l*			
I	2.15	11 923										4	1.8	13.29				8	5 79	13.39*m*			
K	2.79	11.906													1	1.85	13.08*b*	9	7.75	13.32*n*			
J	2.79	11 822	3	2.79	11.82							9	3.31	12.17	5	6.96	12.92*c*	1	1.88	13.31*o*			
L′	5.06	11.609	5	3.11	11.58*a*	Blanchard	1.92	11.34*a*							9	8.32	12.77*d*	7	3.89	13.30*p*			
L	3.63	11.583	7	3.98	11.25*b*										2	1.96	12.29*e*	2	2.40	13.28*q*			
L	5.41	11.216	6	3.57	11.21*c*							8	3.61	11 67	8	7.91	12 28*f*						
I	3.17	11.163	12	2.98	11.14*d*							2	3.86	11.59	6	7.02	12.17*g*				1	3.43	12.71
C	2.29	11.064	4	2.90	11.10*e*										7	7.64	12.05*l*						
E	2.66	11.039																					
B	3.16	10.930	1	2.40	10.91*f*																		
A	3.80	10.834	2	2.54	10.81*g*				4	2.13	10.68												
M	3.03	10.618				Root.....	2.65	10.64*b*	7	5.27	10.57										5	6.12	9.08
F	3.21	10.441				Allen.....	3 59	10.60*c*	1	0.99	10.52												
J	3.84	10.330	8	3.84	10.33	Phleger .	2.83	10.49*d*				6	2.95	10.71									
G	4.40	10.312				Lowe	3.10	10.40*e*															
H	1.59	10.041																					
N	4.44	10 021																					
H	2.38	9.974																					
B	4.15	9.889																					
N	6.70	9.865										3	3.76	9.6							2	10.01	8.24
E	4.00	9.745							3	1.84	9.60	7	4.55	9.13							4	11 80	8.14
D	3.94	9.613																					
M	4.11	9.568																			6	16.08	7 9
D	5.80	9 429							6	3.46	9.21	5	7.51	8 64									
A	4.19	9.145							5	1.94	9.13												
G	5.43	8.397	9	4.02	9.05																		
			11	1.91	8.77																		

all the tests of column VII., nearly all those of column VI., but only a few of the others, were outside of the field. Some of the tests lay so far out of the field as to indicate some abnormal condition or some error. As there is nothing in the construction of the boilers to explain the positions of these tests, they must be due to exceptional qualities of coal, or to errors of test. In the tests in columns VI. and Tests. (The italic letters are the capacity tests.) There were fourteen boilers, erected especially for test and competition. The same coal was used in the tests, and the same experimenter made them. The boilers were new and in excellent condition. It is to be expected therefore that every effort was made to secure the highest possible results. As is the case in every competition between strong rivals,

BOILER TESTS WITH ANTHRACITE COAL. RATIO OF EVAPORATION PER SQ. FOOT OF HEATING SURFACE PER HOUR TO EVAPORATION PER POUND OF COMBUSTIBLE.



The field enclosed by dotted lines contains 22 out of 28 Centennial tests. 8 out of 9 Babcock & Wilcox, marked 5 all Am. Inst. Fair tests, marked Centennial economy test, marked A. B., &c. Centennial capacity test, marked A, B., &c.

VIII. (Isherwood's) there are almost certainly errors due to primage, and they are unreliable from the fact that no priming tests were made, if for nothing else.

The figures in the tables herewith are arranged so as to show in some measure the same facts which the plotted diagram shows more clearly.

Consider column I. the Centennial in good condition for a race, several of the boilers came so close together in the front rank that it is difficult to distinguish between them. The five boilers at the top of the list which were tested with anthracite coal gave results ranging only between 12.094 and 11.822. These results are so close as to be within the limit of accidental variation, and are certainly

within the limit of error of the calorimeter tests, which have been considered erroneous by many good authorities. Rejecting the test with bituminous coal, *L'*, there follow five tests with results between 11 and 11.6 lbs., 8 between 10 and 11 lbs., and 8 between 9 and 10 lbs. With but few exceptions the tendency of the figures is towards decrease of economy with increase of rate of evaporation per square foot of heating surface. If we leave out the Galloway test *L*, the five highest boilers show an average rate of evaporation of 2.66 lbs. per square foot of heating surface, the next four 2.93 lbs., the next eight 3.43, and the last eight 4.41 lbs., which figures would indicate that if the rate of evaporation in the boilers which evaporated less than 11 lbs. of water per lb. combustible had been decreased, the economy of many of them might have been increased so as to bring them into the front rank.

The chief lesson to be learned from the Centennial tests, however, in this connection, is the fact that notwithstanding the great difference in construction of the boilers, the selection of the coal, and the generally favorable conditions of the tests, the highest result obtained by any of the boilers with anthracite coal is only 12.094 lbs. of water per lb. combustible. In a similar trial of five boilers at the American Institute Fair in 1871, column III., the best result is 11.34 lbs. The best result yet published of the Babcock & Wilcox boilers is 11.822 lbs., or, rejecting the calorimeter tests as erroneous, 12.131 lbs. Surely these figures are sufficient to render it extremely probable that higher results than 12.131 lbs. per pound of combustible are not to be expected from such anthracite coal as was used in the Centennial tests, under similar conditions of pressure of steam and temperature of flue, and if any test shows a higher result, it is *prima facie* evidence either that the coal has a higher calorific power than the coal used in the Centennial tests, or else that the test is erroneous. The fact that the Babcock & Wilcox tests have been made with many different kinds of anthracite, and none of them have given better results than were shown in the Centennial tests is also an indication that there is no better anthracite in the market than that used at the Centennial.

Assuming what is probably true, that 80 per cent. of the total heating power of a coal can be obtained in a boiler working with high pressure steam and natural draft, and that the remaining 20 per cent. covers all losses from heat carried away in the gases of combustion, radiation, evaporation of moisture in coal, etc., and that this 80 per cent. was reached in the five Centennial tests showing the best result, say 12 lbs., then the heating power of the combustible portion of the coal is equal to an evaporation of $12 \div \frac{80}{100} =$ 15.0 lbs., and $15 \times 965.7 = 14{,}485$ thermal units.

If we assume, as Mr. Buel does, that the heating value of anthracite is 17,320 thermal units, then the best result obtained at the Centennial would show an efficiency of only 67.5 instead of 80 per cent. It would be difficult to figure up a loss of efficiency in the best of these tests of 32.5 per cent. without assuming an enormous excess of air in the flue gases, an enormous amount of radiation, or else imperfect combustion. It is not conceivable that either of these conditions could be allowed in the five tests showing the best result, and we are forced to the conclusion therefore that the heating value of anthracite coal is not anything near 17,320 thermal units per lb. of combustible, but is more nearly 14,500 thermal units.

But Mr. Buel may answer, all this is pure theory, and is opposed to the actual results obtained from the experiments of Isherwood on Marine boilers, and the experiments on the Stead boiler. The rejoinder is, that the theory is based on a larger number of facts, and better attested than Isherwood's or Stead's, since in neither of these cases was there any competition between rival boiler makers, nor is there any evidence that such precautions were taken to insure accuracy as were taken in the tests at the American Institute Fair and at the Centennial. So convinced am I of the fact that the heating value of American anthracite is not materially greater than 14,500 thermal units per lb. of combustible, and that it is not possible to obtain more than a trifle over 12 lbs. of water evaporated from and at 212° per lb. of anthracite combustible in any high pressure boiler with natural draft, that if I should obtain a higher result in a test, I would discredit

my own figures, and make the test over again.

In column II. I have introduced some figures of tests of Babcock & Wilcox boilers in addition to those given by Mr. Buel. No. 10 is from a test by Mr. Geo. H. Barrus, using a mixture of anthracite screenings and Powelton semi-bituminous. It shows two facts, 1st, that the semi-bituminous coal has a greater heating power than anthracite; 2d, that although the boiler was driven at a very high rate of evaporation it still showed excellent economy, and indicates an error in Mr. Buel's statements that water-tube boilers are not economical at high rates of combustion.

Nos. 11 and 12 are two tests of the same boiler made by myself. No. 11 was with poor pea coal, and No. 12 with clean egg. The higher rate of combustion shows the best result. No. 13 was a test made by my assistant with a semi-bituminous coal. It confirms Mr. Barrus' test, No. 10, in showing that the semi-bituminous coals have greater heating value per lb. of combustible than the anthracites.

Mr. Buel makes another thrust at sectional boilers in respect to their safety. Instead of taking an English experience as old as 1878, in which 79 per cent. of all the boilers are of patterns rarely used in this country, and only 15 per cent. are externally fired boilers, he might have taken present experience in this country, with probably 79 per cent. of externally fired boilers, which are continually exploding with great loss of life, and probably 15 per cent. of sectional boilers, none of the chiefly used and properly designed varieties of which have ever yet been known to explode, except in detail, doing no damage to life.

Considerable space is taken by Mr. Buel in proving that in a boiler with good furnace heating surface this surface evaporates the greater part of all the water that is made into steam by the boiler. In any boiler in which the furnace heating surface bears a large ratio to total heating surface this must follow as a necessary consequence of the law that the transmission of heat varies approximately as the square of the difference of temperatures on the two sides of the plate. It does not nevertheless follow that it is best to design a boiler with large ratio of furnace to total heating surface. The writer has made experiments with Babcock & Wilcox boilers in which the furnace heating surface was materially reduced, by protecting it from radiation from the fire by means of a fire-brick arch. The results were as well as could be expected with the coal used (Penn'a. & Illinois bituminous), and very much better than he obtained with the same coal and the same boiler without the arch, or with the same coal and different boilers, in which the ratio of furnace to total heating surface was quite large.

Mr. Buel depends for a considerable portion of his argument upon the theoretical efficiencies derived from Rankine's formula. To show how much dependence should be placed upon this formula it may be well to refer to Rankine, (Steam Engine and Prime Movers p. 293).

"Hence it may be *expected* that the efficiency of a furnace will be expressed to an *approximate* degree of accuracy by the following formula $\frac{E}{E'} = \frac{SB}{S+AF}$ in which A is a constant which *is to be found empirically*, and is *probably* proportional *approximately* to the square of the quantity of air supplied per lb. of fuel." "B is a fractional multiplier to allow for miscellaneous losses of heat, *whose value is to be found by experiment*." "The formula is of course not intended to supersede experiments and practical trials, nor to give results as accurately and satisfactorily as such experiments and trials, but to furnish a convenient means of *estimating approximately* the evaporative power of fuel in proposed boilers, and the comparative efficiency of different boilers. The formula is framed on the supposition, etc." Rankine's formula was first published in 1859.

In so far as his constants are based on experiment, they are on experiments with boilers of a class not often used in this country for stationary purposes, and with coals which are in every way dissimilar from our anthracites. It is useless therefore to predicate anything concerning the various types of boilers not

known to Rankine in 1859, and fired with coal of a character not known to him, by means of his formula, based as it is on probabilities and suppositions, without first correcting the constants in it, as Rankine himself directed, by means of experiment.

Lest the length to which this article has grown may lead to some confusion in the mind of the reader as to the exact points of my disagreement with Mr. Buel I will restate briefly my positions as follows:

1st, There is no reason to believe that American anthracite coal has a higher heating value than 14,544 thermal units per lb. of combustible.

2d, It is probable that the average air supply to furnaces burning anthracite coal, when it is thoroughly burned, with natural draft, is not much less than 24 lbs. per pound of combustible.

3d, That any test of a boiler at high pressure, with American anthracite coal, and natural draft, which shows a result exceeding 12 pounds water per pound of combustible should be discredited, at least until competing tests by a board of experts, such as the American Institute Fair or the Centennial tests, shall have shown that a higher result can be reached in practice.

4th, That while heating surface in the furnace may transmit more heat to the water than surface which is beyond the furnace, it by no means follows that greater economy will be obtained by making the ratio of furnace to total heating surface greater than now prevails.

5th, That no sound argument can be based on Rankine's formula in relation to American anthracite practice, until the constants in it are corrected by experiments for the particular class of boiler and of fuel in question.

6th, That water-tube boilers do not give inferior results at high rates of combustion, if they are properly proportioned for such high rates, to any greater extent than any other class of boiler.

7th, That notwithstanding the letter of an English authority in 1878 which shows that a certain Insurance Co. had no explosions, disastrous explosions are very common in this country with ordinary shell boilers, while no serious explosion has been known of a boiler properly called sectional.

8th, That the test of the Stead boiler, No. 1, Table XXII., must be discredited, and it is not probable that the Stead boiler can be made to show any better results than 12 pounds of water per pound of combustible when run under high pressure and natural draft, and with coal similar to that used in the Centennial tests.

The Tensity and Pressure of Detonating Gas Mixtures.—MM. Berthelot and Vielle have recently been studying the influence of the density of detonating gaseous mixtures upon the pressure developed. The measure of pressure developed by the same gaseous system, taken under two initial states of different density to which the same quantity of heat is communicated, is an important matter in thermodynamics. If the pressures vary in the same ratio as the densities, we may conclude, independently of all special hypothesis on the laws of gases, first, that the specific heat of the system is independent of its density (that is to say, of its initial pressure), and depends only on the absolute temperature, whatever that may mean; and secondly, that the relative variation of the pressure at constant volume, produced by the introduction of a determinate quantity of heat, is also independent of the pressure and a function only of the temperature. Lastly, the pressure itself will vary proportionally with the absolute temperature, as defined by the theory of a perfect gas, and will serve to determine it. MM. Berthelot and Vielle operated with a bomb, at first kept at ordinary temperatures in the air, and afterwards heated in an oil bath to 153 deg. Cent. They also employed isomeric mixtures of the gases, methylic ether, cyanogen, hydrogen, acetylene, and other gases were experimented upon, and the general conclusions are as follows: 1. The same quantity of heat being furnished to a gaseous system the pressure of the system varies proportionally to the density of the system. 2. The specific heat of the gas is sensibly independent of the density as well towards very high temperatures as about 0 deg. Cent. This is all true for densities near to those that the gas possesses cold under normal pressure, and which varied in the experiment to double the original value. 3. The pressure increases with the quantity of heat furnished to the same system. 4. The apparent specific heat increases parallel with this quantity of heat. These conclusions are independent of all hypotheses on the nature and laws of gases, and were simply drawn from the experiments in question.

EXPERIMENTS WITH COMPRESSED GUN COTTON,

CONDUCTED IN THE MANUFACTORY OF MAX WOLFF & CO., WALSRODE.

BY THE SUPERINTENDENT, MAX VON FORSTER, Engineer, Premier-Lieutenant a. D.

Translated from the German, with consent of the Author, by Lieut. JOHN P. WISSER, U. S. Army.

The following experiments have for an object to determine in what manner compressed gun-cotton should be applied to obtain the greatest and most useful effects. Many experiments have already been made with this object; it is difficult to arrive at correct results since we have no accurate instrument for measuring the force of quick-burning explosives.

Nevertheless, the author believes that, assisted by his long-continued practice in military and civil work with explosives, he has been able, supported by the following experiments, to arrive at an approximately correct conclusion on the effects of the various kinds of explosives.

The differences in effect between the less rapid-burning and the more rapid-burning, between the rapid-burning and the slow-burning, are so marked that they may be easily observed, and compel the admission that certain conclusions may be drawn therefrom.

Moreover, as superintendent of a gun-cotton factory, the author has the opportunity, and it is in fact his duty, to work with this explosive; material, time and place are always at his disposal for these investigations, so that he may hope to have made some progress in the preparation of gun-cotton, as well as a few observations on its properties. The author will, nevertheless, be very grateful for every correction, and also for any contributions on other experiments in the same field, and will gladly modify his views through other obtained results, continuing, meanwhile, his own researches.

The gun-cotton used is, unless otherwise stated, such as is prepared in Germany and other states for military purposes, and is made in the factory of Messrs. Wolff & Co., Walsrode. It contains 12.3 per cent. nitrogen in the ash-free substance, and is in the form of cylinders 30 mm. in diameter and 70 mm. or more in height, and has a specific gravity of one; a few pieces of larger diameter, having a specific gravity of 1.1 are also employed.

By *dry gun-cotton* is understood that which has been dried until its weight is constant, and has then absorbed about 1 per cent. of moisture from the atmosphere.

Wet gun-cotton has absorbed in 100 parts of gun-cotton by weight the parts of water given, mostly 25 per cent. For the detonation of dry gun-cotton primers (called detonators) are used, containing 1 grm. mercury fulminate, which are fired partly by electricity, partly by means of Bickfords' quick-match.

The object to be exploded consists of a leaden cylinder 46 mm. in diameter, set upon a small iron plate lying on the solid ground. The cartridges are placed on the leaden cylinder.

It is to be remarked that the cartridges have a greater effect on the shorter than on the longer leaden cylinders, that therefore only those explosions, which occurred on cylinders of the same height, can be directly compared.

The annexed drawings exhibit the leaden cylinders in cross-section and plan, after the explosion.

Following the experiments on the effects of explosion are given certain observations on, and other experiments with, compressed gun-cotton.

1. EXPERIMENTS ON THE EFFECTS OF EXPLOSION.

In Plate 1 the explosions Nos. II., III. and IV. were made with cartridges of 50 grm. gun-cotton 70 mm. long; Nos. I. and V. with cartridges of greater weight, but also of greater length; the increased weight had no increased effect, on the contrary, the effect in case of the longer cartridges was diminished.

The explosions VII., VIII. and IX. were produced by cartridges of the same size as II., III. and IV., not solid, how-

ever, but hollow, as shown in Plate 1, Figure 2.

The effect on the leaden cylinder is greater in case of the hollow cartridges although the solid ones were greater in weight.

The explosions VI. and X. are analogous to I. and V., with cartridges of greater weight, but also greater length, than VII., VIII. and IX. The effect of both is again less than of those conducted with less weight.

It follows therefore, that in case of dry gun-cotton no increased effect is produced by increasing the charge, if at the same time the length of the charge is increased; furthermore, it appears that in a long cartridge of dry gun-cotton the upper parts cannot transmit their detonation to the lower parts in the same explosive shock as that effected by the initial detonation of the primer, and hence it follows that in long charges of dry gun-cotton it is better to use several primers, placed some distance apart, and to fire them by electricity, in order to produce the greatest possible effect of the total charge.

These relations are more apparent in case of gun-cotton mixed with saltpeter and of wet gun-cotton.

In Plate 2, IX. is a cartridge of gun-cotton intimately mixed with 50 per cent. barium nitrate ("Baryt saltpeter"), constituting an almost homogeneous mass. The cartridge is 70 mm. high, weighing 65 g.; the explosion VIII. is of a similar cartridge, but 220 mm high and weighs 225 g.; now, although the effect of the latter cartridge is not increased in proportion to the increased weight, it is nevertheless greater on the whole, and indeed considerably greater than in the former cartridge, while in the case of dry gun-cotton the effect was diminished.

Explosion X. consists of two wet cartridges with 25 per cent. water, and a dry one of 50 g. for the production of the detonation.

Explosion XI. consists of three wet and one dry cartridges.

The effect of these two explosions is the greatest of those thus far described; it is considerably greater than that of the dry priming cartridge alone, and much greater than that of the long charges of dry gun-cotton. In case of the wet gun-cotton the detonation was propagated with at least equally great suddenness throughout the entire length of the charge. Moreover, the wet gun-cotton is, on the whole, more sudden in its effects than the dry.

The dry gun-cotton depresses the center of the leaden cylinder and bends the edges over, but both parts have, nevertheless, a smooth surface; in case of the wet gun-cotton the part of the lead referred to was torn and pulverized.

Similar effects have been obtained with the very sudden explosives prepared from nitric acid and binitro benzole, as well as from nitrous acid and sulphocarbides.

Professor Abel, in his highly important experiments, described in Dingler's Polytechnisches Journal, 1874, has shown that the rapidity of propagation of the detonation of dry gun-cotton is considerably less than of wet gun-cotton; the above experiments show that this is also true with respect to the *effects* of the two kinds of gun-cotton; furthermore, that in a long charge the effect itself of the dry gun-cotton diminishes towards the end of the charge, while that of wet gun-cotton does not.

Professor Abel found, further, that in long charges of gun-cotton the rate of propagation of the detonation was uniform, being as great in the last meter as in the first. But he used gun-cotton with 30 per cent. water; for, otherwise would have been the results had dry gun-cotton been used. This will probably have a slower rate of detonation towards the end of the charge.

Professor Abel says, moreover, p. 318, Dingler's Journal, 1874:

"The more energetic action produced when gun-cotton and its preparations are detonated in a moist condition, has furnished the striking proof that the detonation is transmitted the more easily, and the transformation of solid to gas and vapor takes place the more suddenly the less the compressibility of a given explosive mass subjected to the action of a sufficient initial detonation. Since the water replaces the air contained in the compressed masses, the propagation of the detonation will evidently be favored by the increased resistance which the particles offer during the instant of detonation."

True as these propositions are they do not explain the difference in action re-

Fig. 1.

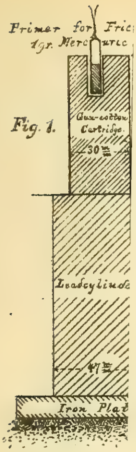


Fig. 2.

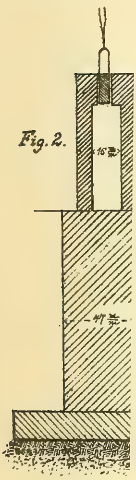


Fig. 3.

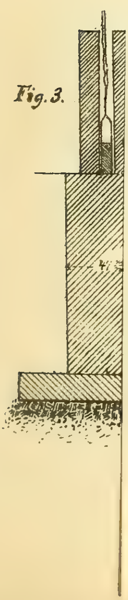


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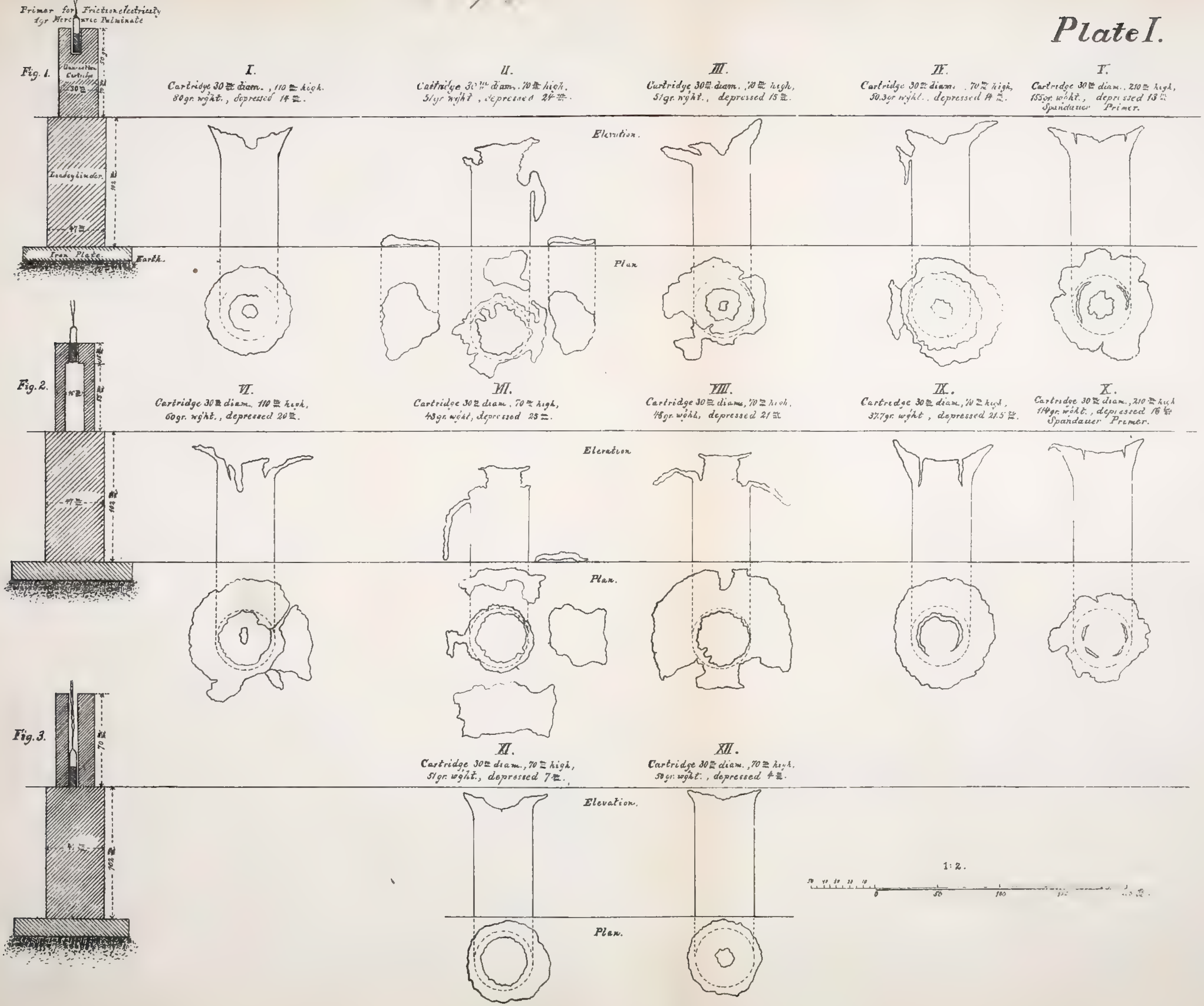
Plate I.



ferred to between dry gun-cotton and wet gun-cotton containing 30 per cent. of water. The latter is more easily compressible and less compact than dry, and is much more easily subject to being crumbled and torn up than the dry. When it is desired to work over dry pieces of gun-cotton in the factory, which must therefore be first crumbled, they are moistened, because they are then more easily crumbled. The particles of a wet cartridge will probably offer a much smaller resistance to the initial detonation against tearing and dispersion than those of a dry cartridge.

The initial detonation acts principally by the shock; when this strikes a dry cartridge filled with air the air acts to diminish the shock; because it is elastic it is compressed and transmits a slighter shock than it received. The water in a wet cartridge is not compressible; it transmits the received shock with a force equal to that which it received.

The explosions Plate 2, I., II. and III., exhibit a clear view of the necessity of giving the charge and the object to be destroyed the largest possible surface of contact, and the charge itself the least possible height.

No. I. is 18 mm. high, No. II. only 13 mm., but has a larger surface of contact with the leaden cylinder; the latter has produced a greater effect than I. in spite of its less weight; explosion III., with triple the weight, but also triple the weight of charge of II., has accomplished but little more than the latter.

The same effect of the form of the charge is shown in Plate 2, explosions IV. and V., and also VI. and VII.

Explosion VI. has a flat charge, lying close to the object, and has acted with considerably more force than VII., in which the same weight of gun-cotton is applied in a high and narrow form.

In all these results it is remarkable that the difference of effect is already apparent with small differences in dimension; a charge 13 mm. high acts more energetically than one 18 mm. high, and a still greater difference is found in the action of one 30 mm. high, and another 68 mm. high of equal weight.

If we place a piece of compressed gun-cotton on a piece of iron, an accurate impression of the form of the under surface of the gun-cotton is produced by the detonation; the gases acting on the iron have occupied exactly the same space, and no more, that the solid explosive previously occupied. As long as the detonation gases act they have not yet expanded on the whole.

Every angle, every depression, every indentation present in the piece of gun-cotton, is copied by the gases and impressed on the underlying iron, and we may also conclude herefrom that only the gases evolved by the very undermost layer of gun-cotton act on the iron, while the others are lost.

If we observe the action of compressed gun-cotton, as compared with that of dynamite, on compact rock, with the application of drill holes, it will be found that gun-cotton destroys the interior of the drill hole, that it completely pulverizes the rock, but that it does not eject the pieces as dynamite does. The action of gun-cotton seems to be more sudden, but more local, than that of dynamite.

If we could give the gases of the detonated gun-cotton a fixed direction towards the object the effect would be increased. The experiments here given furnish two means of attaining this end to a certain degree.

In Plate 1 the primers are set in the cartridge on the side opposite the object to be destroyed in all the explosions, except XI. and XII., in which the primer is placed in that part of the cartridge which is in contact with the object. The effect of these last two explosions is much less than that of the others.

The detonation of the primer gives the detonation gases a direction away from itself, a direction towards the side opposite.

This fact may be explained by the transfer of the vibrations of the gases of the primer to those of the gun-cotton, when the gases of the primer have a fixed direction. Simpler is the explanation that the detonation gases of the primer form, to a certain extent, a dam, so that they offer from the beginning a resistance to the gases generated from the gun-cotton, and thus press them toward the other side. Even a very weak dam of loose earth acts on the gases of the explosive, why not the energetic detonation of the mercuric fulminate?

At what point in the cartridge the original direction of the gases is main-

tained has not yet been determined; according to the experiments here given, the distance does not seem to be very great, but the direction given by the initial detonation, in case of a cartridge of a weight of over double the diameter, 70:30, becomes quite noticeable. In explosions in a closed space the same phenomena occur, as illustrated in Plate 2, explosion XV.

The cartridge is here enclosed in a block of lead, and the opening, through which the cartridge was introduced, is closed by a leaden stopper. The latter is fastened with iron bands. The cartridge is therefore enclosed equally firmly on all sides. The primer is not introduced into the cartridge but is simply in contact with it.

In this explosion, a circumstance unfavorable for this phenomenon was that the enclosing of the cartridge was not complete, since the iron bands, which held the leaden stopper, were fractured by the explosion, so that the stopper was carried away, and gases were enabled to escape prematurely on the side of the primer. Otherwise the action would have been even more energetic than it actually was.

The primer must therefore always be placed on the side opposite the charge.

The second method of giving the detonation gases a fixed direction, consists, according to the experiments, in furnishing the cartridge with a hollow opening, on the side opposite the primer and adjacent to the object to be destroyed. Explosions VI.-X., Plate 1, furnished with hollow cartridges are, on an average, considerably more violent than I.–V., although the latter were of the same size, but greater in weight, since they were solid.

An increased action, in case of the hollow cartridges, takes place exactly in the direction of, and over the entire cross-section of the opening. More clearly is this shown when, in place of lead, the more brittle metal, iron, is taken as the object to be destroyed.

In explosions XII.–XIV., Plate 2, wrought iron was selected as the object. In XIII. and XIV. a strong impression of the cross-section of the hollow opening of the cartridge appears, which is twice the depth of the impression produced by a solid cartridge as in No. XII.

On the whole, the effect of hollow cartridges is greater than of solid cartridges of equal size though greater in weight.

In explosions where the space, in which the explosive charge is placed, is limited, as in the explosive charges of shells, in which the explosive charge and the object to be exploded cannot receive a larger surface of contact than that of the interior of the shell, it is best to apply both means described, viz.: the hollowing of the charge and the placing of the primer at the base of the shell, in order to obtain an increased action towards the head of the shell, in which direction also the object to be destroyed will almost always lie.

The use of wet gun-cotton instead of dry will also offer extraordinary advantages.

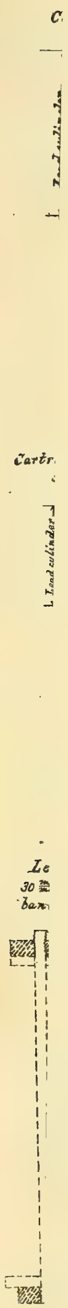
In the application of gun-cotton it must be added that, aside from the fact that the action of the explosive charge is greater, the wet gun-cotton, as is well known, is much less dangerous in the preservation and handling thereof than the certainly very slightly dangerous dry. The combustion of a large supply of gun-cotton, and hence a loss thereof by fire, will be prevented by wet storage of it.

2. COATING OF GUN-COTTON BY MEANS OF A SOLVENT THEREOF.

Compressed wet gun-cotton has many inherent disadvantages: the water evaporates readily, and the cotton must therefore be moistened again from time to time (although this may be greatly diminished by good packing and storing in magazines), moreover wet gun-cotton crumbles easily, and even very well packed wet gun-cotton may suffer much in long-continued transportation, finally it is subject to the formation of fungus, which will in time destroy its structure. It may be remarked, in passing, that the formation of fungus is favored by the presence of paper in the packages, which shall therefore be carefully avoided.

The author has, however, discovered a process for avoiding or largely diminishing the above-mentioned objections to wet gun-cotton. It is as follows:

If we dip pieces of wet gun-cotton for a short time, $\frac{1}{4}$–$\frac{1}{3}$ minute, into good acetic ether, into nitro-benzole, or into other solvents of gun-cotton, then take them out and allow the solvent to evaporate,


Lead cylinder

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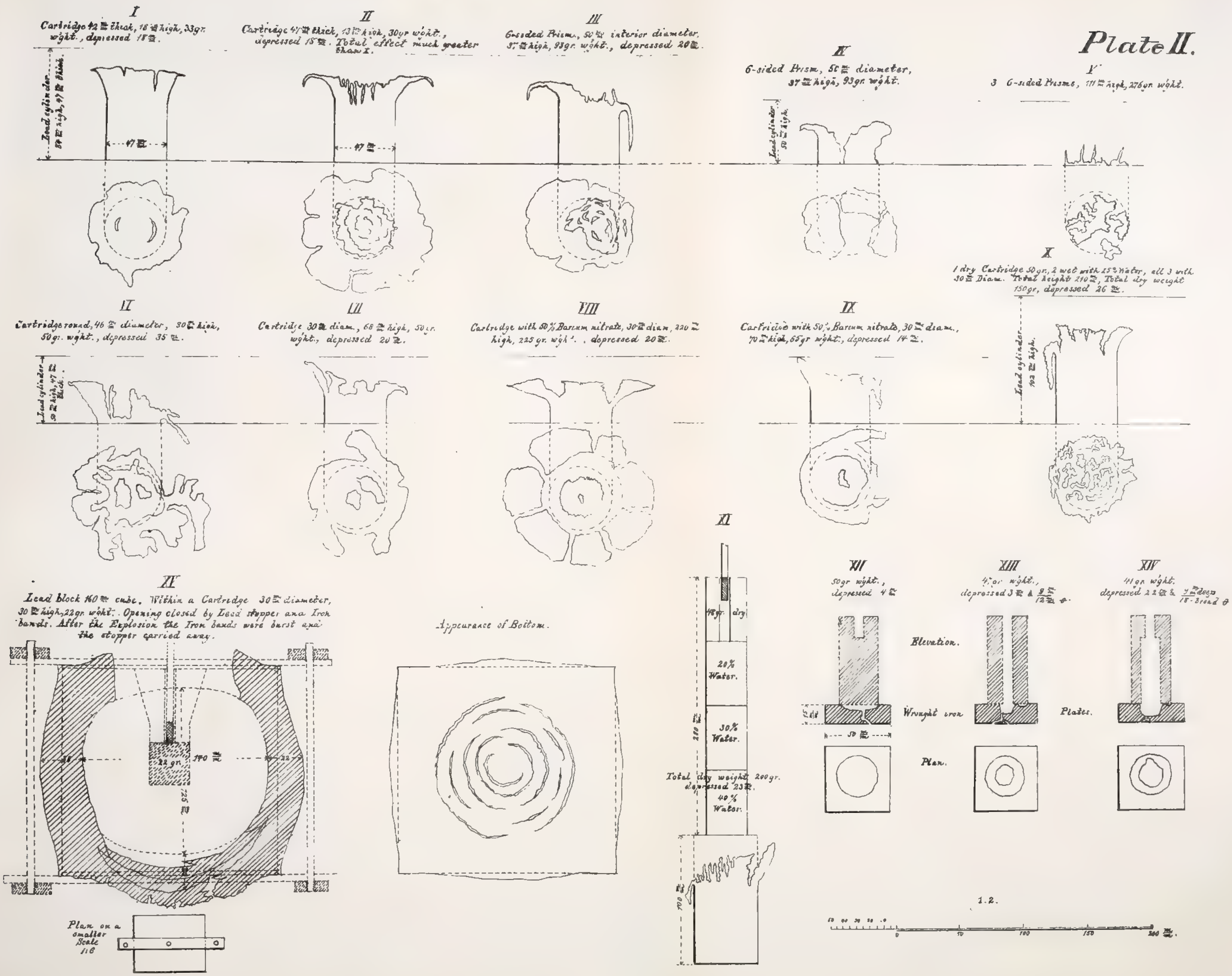


Plate II.
I
Cartridge 42mm thick, 18mm high, 33gr. wght., depressed 18mm.
Lead cylinder 50mm high, 47mm thick.
47mm
II
Cartridge 47mm thick, 13mm high, 30gr wght., depressed 15mm. Total effect much greater than I.
47mm
III
6-sided Prism, 50mm interior diameter, 37mm high, 93gr. wght., depressed 20mm.
IV
6-sided Prism, 51mm diameter, 37mm high, 93gr. wght.
Lead cylinder 50mm high.
V
3 6-sided Prisms, 111mm high, 276gr wght.
X
1 dry Cartridge 50gr., 2 wet with 25% Water, all 3 with 30mm Diam. Total height 210mm, Total dry weight 150gr, depressed 26mm.
Lead cylinder 103mm high.
VI
Cartridge round, 46mm diameter, 30mm high, 50gr. wght., depressed 35mm.
Lead cylinder 50mm high, 47mm thick.
VII
Cartridge 30mm diam., 68mm high, 50gr. wght., depressed 20mm.
VIII
Cartridge with 50% Barium nitrate, 30mm diam, 220mm high, 225 gr. wght., depressed 20mm.
IX
Cartridge with 50% Barium nitrate, 30mm diam., 70mm high, 65gr wght., depressed 14mm.
XV
Lead block 160mm cube. Within a Cartridge 30mm diameter, 30mm high, 22gr. wght. Opening closed by Lead stopper and Iron bands. After the Explosion the Iron bands were burst and the stopper carried away.
22 gr.
140mm
125
Plan on a smaller Scale 1/6
Appearance of Bottom.
XI
48gr. dry
20% Water.
30% Water.
210
Total dry weight 200gr. depressed 23mm.
40% Water.
100
XII
50gr wght., depressed 4mm.
XIII
45gr wght., depressed 3mm & 9mm/12mm ⌀.
XIV
41gr wght. depressed 22mm & 7mm deep/18 - broad ⌀
Elevation.
Wrought iron Plates.
50mm
Plan.
1.2.
50 40 30 20 10 0 50 100 150 200mm.

there will be formed on the piece of gun-cotton a very thin, but very compact coating, which gives it a very firm shape, protects it against crumbling and prevents fungoid growth.

This coating, which consists of dissolved gun-cotton, and which should be absolutely water-tight, nevertheless does not protect completely against the gradual drying of wet gun-cotton; there are formed in the coating very fine, invisible cracks, through which the water, though slowly, evaporates.

A piece of gun-cotton not thus coated, containing 25 per cent. water, will become air-dry (*i.e.*, with 2 per cent. moisture) in summer in a current of air, in several days, whereas in case of gun-cotton coated by means of ether, etc., several weeks will be required. The dried piece placed in water takes it up again. But this does not proceed very rapidly; in case we wish to effect the absorption of moisture quickly, in 1–1½ hours, we can, in the process of manufacture, leave little uncoated spaces in the coating, through which the water may penetrate rapidly.

The process described can also be applied with advantage to dry gun-cotton.

If we coat a piece of dry gun-cotton, supplied with an opening for the reception of the primer, by means of a solvent, the gun-cotton will *first*, as in the case of wet gun-cotton, receive a firm, permanent form, and *secondly*, the cartridge, as well as the opening for the primer, will be protected against moisture, without interfering with the introduction of the primer, as would be the case were the opening specially closed by a sheet of paper, and also without diminishing the capacity to explode, as would be the case were the opening lined with copper, etc. The thin coating of gun-cotton offers no resistance to the action of the primer; many experiments have proven that such cartridges will detonate with a ½-grm. primer. Moreover, such a cartridge can be used under water directly, without the necessity of introducing the primer water-tight.

It is possible to prepare pieces of gun-cotton, by means of such a coating, so water-tight that when placed in water for several weeks they will not increase in weight; however, this does not always succeed as in this case also small cracks seem to be formed. The author has therefore more recently coated only the walls of the opening for the reception of the primer by means of ether, and rendered the other portions impermeable by dipping them in melted paraffin. By this means water-tight cartridges have been uniformly obtained.

The opening for the primer may also be made water-tight, by lining it with copper, etc., but there follows a great objection in that the capacity to explode readily suffers, since, *first*, a layer of air forms between the gun-cotton and the lining, *secondly*, the lining must be broken by the primer, and *thirdly*, another layer of air, or, in case of explosion under water, a layer of water, exists between primer and lining.

It happened often to the author that, in explosions under water, when the priming cartridge was adjusted by a copper lining, in spite of the use of the best primers, the gun-cotton charge began to burn indeed, or to decompose into dense red fumes, nitrous acid fumes, etc., but did not detonate.

This decomposition of gun-cotton into nitrous acid fumes, etc., caused by an insufficiently energetic initial detonation of the primer, appears not to have been elsewhere noticed.

In the manufacture of gun-cotton, during the nitration of the cotton, this decomposition is of common occurrence when the temperature rises too high.

The process of rendering the opening for the primer impermeable through ether coating may furthermore be of importance when wet gun-cotton must remain in close contact for a considerable time with the dry priming-cartridge, since, in case it is not made impermeable, it is to be feared that the evaporation from the wet gun-cotton will moisten the dry. This takes place very easily and rapidly, and can hardly be avoided in case one may wish to use both wet and dry gun-cotton as in shells.

The principal advantage of the process described is that it gives the wet gun-cotton a permanent form, and thus renders it applicable in war.

3. SPONTANEOUS DECOMPOSITION OF GUN-COTTON.

The author is in possession of a piece of compressed gun-cotton of the year 1878, which, in the process of manufac-

ture, was not completely washed, so that some acid remained. The piece was preserved during this time in a chest kept in a dry place. It is now completely decomposed, and has become a greenish, soft mass, which has lost the structure and appearance of gun-cotton, and, when pressed, yields a glutinous liquid. It smells sour, burns when ignited with a white flame (gun-cotton with a red flame) and emits no appreciable vapors. In an air-tight preserving-jar, in which a part of this experimental prism of gun-cotton was preserved, no pressure has been noticeable since the decomposition has set in.

This phenomenon shows that the spontaneous decomposition of poor gun-cotton takes place without the production of flame, and the author believes that a spontaneous combustion of gun-cotton has never occurred. Of course, gun-cotton subjected to high temperatures, such as can only be brought about artificially, temperatures above 120° C., is not here included. Good gun-cotton is sufficiently stable for all practical purposes.

How many unforeseen accidents may cause combustion is proven by the following experiment, communicated to the author by Professor Kraut, in Hanover.

If we take a good handful of simple cotton wadding, set a portion of it on fire and wrap the other part around the kindled point, so that the air is excluded, the piece of wadding may be wrapped in paper and preserved for months.

If, at the end of this time, the wadding is unwrapped and air admitted, the part kindled months before goes on burning and consumes also the rest of the cotton.

How often may this phenomenon have occurred when, in case of a combustion of ordinary cotton in large bulk, it was said to be due to spontaneous combustion. With gun-cotton it was probably often the same.

4. AN EXPLOSION UNDER WATER.

It would be of great interest if a charge of gun-cotton, which has been placed under water, could be preserved explosive for a fixed time, and be so arranged that, after another fixed time, it will cease to be explosive, and thus render itself inexplosive.

This would be of importance in all blastings of rocks in the beds of rivers, in harbors, etc., because in these cases ships and workmen in diving-bells and diving-clothes must approach the point of explosion in order to undertake the work of clearing away, and to accomplish this work pounding and striking with heavy iron tools is necessary, by which after-explosions of charges which had missed fire may occur.

It may furthermore be of importance in the laying of sub-marine mines, which need be operative but for a limited time, and must not be dangerous to our own shipping thereafter, and must moreover be capable of being raised without danger.

The author hereof has discovered a method of procedure which meets these requirements.

When a cylinder of compressed gun-cotton is so enveloped that only the bottom, that is, the part opposite the primer, is not water-tight, and is set in water, the latter will gradually penetrate into the cartridge from the bottom upward and thus wet it. When the water has nearly reached the primer, and an amount of dry gun-cotton is therefore present, not sufficient, even if it detonates, to cause the detonation also of the wet gun-cotton, the charge or mine is no longer capable of detonating, and becomes perfectly safe.

In a short while the rest of the dry gun-cotton becomes wet and the priming will be entirely useless.

Therefore, in explosions with gun-cotton under water a priming-cartridge, as above described, is used, the rest of the charge being composed of wet gun-cotton.

The priming-cartridge is easily enclosed so that only the bottom thereof is permeable to water by enveloping it in a rubber tube open below, in the upper part of which the priming is tied water-tight. The cartridge may also be made impermeable by means of paraffin or a coating of ether, and the bottom then cut off. The coating with ether has the great advantage that the opening for the primer is made impermeable at the same time. The coating produced by ether is sufficient also in itself, without the rubber tube.

In the case of sub-marine mines many other absolutely safe means naturally offer themselves for the preparation of

the priming-cartridge, according to the same system and for the purpose in view.

A cartridge of pure gun-cotton, of specific gravity 1.1, 100 mm. high, remains explosive for about 8 hours, and in 11 hours is completely wet and entirely incapable of being exploded by shock. A cartridge of gun-cotton mixed with saltpeter remains dry longer than one of pure gun-cotton.

The specific gravity, the length of the cartridge, and the extent of surface through which the water can penetrate, constitute factors sufficient to determine satisfactorily, within certain limits, the time during which the charge will remain explosive, since, with proper care, cartridges may be furnished sufficiently uniform in character to produce a uniform action.

ELECTRICAL CONDUCTORS.

By WILLIAM HENRY PREECE, F. R. S., M. Inst. C. E.

Proceedings of the Institution of Civil Engineers.

II.

DISCUSSION.

Mr. Brunlees, President, said he thought the discussion might well be taken in three parts. First, as to the qualities which electrical conductors should possess; next, as to the manufacture of the conductors, and then, having the electrical conductor according to the conditions laid down by men of science, and according to the possibilities of manufacture, on the practical use of the conductor. He would first ask Mr. Preece if he desired to add anything before the discussion commenced.

Mr. Preece expressed his deep regret that one seat at the Council table was empty, a seat that had been filled by one who had taken a prominent part in the discussion of every electrical paper brought before the institution. The late Sir William Siemens had taken the deepest interest in the subject, and had succeeded very largely in enriching it. Mr. Preece had brought forward many facts to illustrate the improvement effected in electrical conductors during the last quarter of a century, and he hoped that the discussion would elicit other facts, showing how the mechanical and electrical qualities of the various metals had been almost metamorphosed. The chief point that he desired to emphasize was the position that copper was likely to take in the future, and the remarkable mechanical powers that it evinced. He had brought for inspection a number of specimens illustrating the behavior of metals and showing how they were produced. In speaking of them in his paper he had been compelled frequently to use a term which was familiar in the mouth of every electrician as a household word, but which had not yet become familiar to engineers—the term "resistance." He had spoken throughout the paper of the resistance of wires, knowing well, as an electrician, what the term resistance meant; but many engineers assumed that it meant mechanical resistance—resistance to tension or to rupture. It was a misfortune that the term had been too freely introduced, and it would have been better if he had spoken entirely in terms of conductivity. If he had said that a copper wire conducted electricity six times better than iron wire of the same dimensions, he should have been better understood than by saying that a piece of wire had one-sixth of the resistance, or six times the resistance, as the case might be. Sir William Thomson had pointed out in that room how it was that conductivity was the exact reverse or reciprocal of resistance, and he went so far as to suggest that there ought to be a standard for conductivity, as there was a standard for resistance. That point had not, however, yet been reached. But, should he still use the term "resistance," he wished it to be clearly understood that he meant by it the reciprocal of conductivity. Resistance was expressed in terms of a standard called the ohm, and he believed the day was not far

distant when every one would know what an ohm was as well as what a foot was, or what a meter was. The ohm standard was expressed by a certain length, a column of mercury, about 1 meter in length, of 1 square millimeter section. But in dealing with copper and with iron, a standard had been introduced expressed in weight per mile. Copper wire weighing 842 lbs. per mile gave an ohm, and was called a mile ohm of copper; iron wire weighing 4,500 lbs. gave a mile ohm of iron; so that the relative dimensions of that curious standard depended both upon length and weight. He had brought for exhibition the various instruments that were used to test the metals, and he would show the test upon iron, and, if time permitted, upon copper, for he wished the members to have distinct evidence of the remarkable mechanical qualities of the copper produced at the present day. The copper wire specimens on the table possessed a breaking strain of 30 tons on the square inch, while the iron used for telegraphic purposes possessed a breaking strain of only 22 tons. Again, there was an impression that copper was very plastic, and that it stretched very considerably; but he had figures showing that it did not stretch so much as iron; indeed, the copper wire then used stretched considerably less than iron; so that in both properties, tensile strength and elasticity, the copper of the present day was better than the iron. The machine exhibited was that used for testing the breaking strain. There was a system of levers and a shifting weight. As at present arranged, the machine would register from 1 lb. to 5,000 lbs. There was a length of wire applied which was clamped in such a way that there was no nipping or biting, and it suffered no mechanical injury. When, by means of the wheel and the multiplying gear, a slow motion was brought to bear, a weight was gradually applied to the wire until it broke. The piece of wire tested weighed 400 lbs. to the mile, and it was known as 7½ by the centimeter gauge. (The wire was then tested for tensile strength.) The wire, it would be seen, had broken at 1,160 lbs., the specified breaking strain being 1,080. It was also necessary to record the stretch, which was sometimes done at the same time; but it was better to do it independently. The second machine exhibited, clamped, a length of ten inches. (The wire was here tested for stretch.) The wire, it would be seen, had given way after stretching 15 to 16 per cent. Another test was the torsion test—a test for torsive capacity. It was not desired that the wire should resist torsion, but should bear torsion. By making an ink mark along the top, and by twisting the wire in the other machine until it broke, a series of spirals was formed, and the number of the spirals indicated the torsive capacity. All wires were specified to show a certain number of twists. The wire experimented upon was taken from a coil of No. 7½, and all the pieces had been cut off the same length. He would next experiment upon copper wire No. 14. Meanwhile he would refer to the enormous advantage which copper wire would give for overhead purposes. There was then going on what he had characterized as a meaningless crusade against overhead wires. Vestries and other small corporations in outlying districts were endeavoring to force the Government to put the wires underground, and the newspapers were bringing forward the fact that even in Germany and France the wires were so placed. It was not sufficiently known that Germany and France were only doing what had been done in England a quarter of a century ago. The wires were then placed underground; all the main wires in the country between London, Birmingham, Liverpool, Manchester, Leeds, and all the wires to the cables on the south coast, were underground; but after sufficient experience of their use it was found necessary to take them up again; and he should not be in the least degree surprised to find the same result taking place, sooner or later, in Germany and France. It had been found that wires overhead had many times the efficiency of wires underground, and it was absurd to try and force electricians to do an act that was commercially wrong and practically foolish, for the imaginary reason that overhead wires were supposed to be dangerous. Statistics showed that in the United Kingdom there were 18,000 persons killed by accident every year. The average for the last thirty years—during the period of telegraphs—was about 12,000

per annum. In that period about 400,000 persons had been killed by accident, and of that number two only had been killed by telegraph wires. One of those accidents was owing to the foolish practice he had lately seen suggested, even in the *Times*, of having the wire tied to the railing of an area. If, in that case, the wire had been allowed to hang free, it could not have produced any injury. With the light, fine copper wires at present used, it was scarcely possible to conceive that if they did break they could produce any harm. Why, then, should legislation be enacted for such a minimum of accident as was shown by the statistics to which he had referred? He granted that the wires were very ugly, and no one going through Moorgate Street or Leadenhall Street could help being vexed to see the metropolis so much disfigured. That, however, was not because the wires were overhead, but simply because they were carried in a higgledy-piggledy, spider-web fashion, in any direction, without method or system. If the corporations wanted to do good it should not be by trying to force the authorities to place the wires needlessly underground, but by trying to exercise some control over those who erected wires overground. It had been thought, from the remarks he had made about the gauge, that he expressed disapproval of the gauge recently introduced by the Board of Trade; that, however, was not his object. The gauge was a very good one. It had been accepted by nearly everybody; it had been authorized, and it would do a certain amount of good. But what the Post Office objected to was that there should be so many changes. When it was found that a wire which had been known by their men as No. 8, was called at another time No. 7½, and at another No. 7¾, they decided, in order to avoid confusion, to abandon the gauge altogether, and simply to speak of the wire as of so much weight per mile. That method had been introduced into India with great success. He had stated that the great improvements in the manufacture of iron were due to the care bestowed upon the specifications of the authorities at the Post Office. He ought to add that the improvement was also due to the great care taken by the India authorities in improving the specification. (The copper wire was here tested.) It would be seen that the piece of wire experimented on had stretched 0.15 in 10.2 inches, or nearly 2 per cent. The other piece of wire was eighty-one thousandths of an inch in diameter, and it ought, by specification, to break at 320 lbs., which would be 27 tons on the square inch. It actually broke at 362 lbs., or 31 tons on a square inch.

Sir Frederick Abel, C. B., Honorary Member, said that his remarks should be mainly with the view of eliciting further information, and, if possible, of adding a few supplementary facts with reference to certain points dealt with in the paper. Reference had been made to the remarkably useful work done by the late Dr. Matthiessen, as far back as 1860, in regard to the influence exerted by different commercial impurities in copper upon its conductivity or electrical resistance. The author had correctly stated that those researches had not only greatly instructed them with reference to their knowledge of copper as an electric conductor, but had also led, in a very important degree, to improvements in the treatment of copper, with special reference to the production of electrical conductors. It was stated in the paper that Dr. Matthiessen had determined the electrical resistance of pure copper; but he was not quite sure whether, in the present day—twenty-four years after the experiments—whatever reliance might be placed on the results obtained, the measurements given could be accepted as truly representing what the resistance of perfectly pure copper should be. Electricians had acquired a considerable amount of additional information, and they were on the way to acquire still more in regard to the influence of very minute proportions of impurities upon the electrical conductive powers and other physical properties of metals; and no one could teach them more in that direction than Professor Hughes, who had recently been pursuing some very remarkable researches. Therefore, although they still accepted with great confidence the results of Dr. Matthiessen, they might probably learn yet more with regard to the conductivity of really pure copper. In reference to the manufacture of copper wire, the author had mentioned that soft copper always gave a higher conductivity than hard-

drawn copper, its tensile strength being, of course, considerably lower. On that point he would ask the author to furnish additional data. In some experiments that he had made, which, though few, had been carefully conducted, he had found that the conductivity of a particular sample of copper varied but little, whether it is in the hard-drawn or in the annealed state. Dr. Matthiessen had mentioned that it varied about 2 per cent., but in some recent experiments Sir F. Abel had found that there was no practical difference between the conductivity of certain samples of copper, containing but a small proportion of chemical impurity, when this was in the hard-drawn or the annealed condition. In one experiment, with a length of 15 feet 6 inches of copper, he had obtained 0.0257 ohm resistance with the hard-drawn, and 0.02515 with the annealed. The very slight variations might almost be variations due to experimental error, even though when multiplied upon a statute mile the difference was more appreciable. Taking the numbers upon a mile of wire they would represent, in the case of the hard-drawn wire, 8.707 ohms, and in the case of the annealed wire 8.520 ohms, showing even thus only a very small difference. He might be allowed to allude in passing to what the author had said in reference to what appeared to be the influence of currents upon the durability of a conductor. Electricians had still much to learn in that direction. Many persons believed that important alterations in the physical structure of copper and of metals generally, were effected by the continuous or intermittent passage of currents through them. He thought, with the author, that further information was necessary on that point. One thing was worthy of notice, namely, the influence of small quantities of impurities which would be detrimental to copper as a conductor, when contained in the india-rubber or other materials used as dielectric coatings. Minute quantities of sulphur, for example, in india-rubber, would find their way into copper wire coated with it, and exert a detrimental effect on the metal as a conductor. It was that which led Mr. Hooper to devise the very pretty method—which, however, was only partially successful—of keeping vulcanized india-rubber from direct contact with copper wire coated with it, by introducing india-rubber between the vulcanized rubber and the copper itself. As to the question of purity of copper, the author had referred to the very great advantage which had been conferred by improvements in the metallurgical treatment of copper upon the product, so far as electric conductivity was concerned. He had mentioned the "best selected" copper as the material which gave the best forms for wire which could be obtained until certain high qualities of copper were brought from Australia, Lake Superior, and other places. The quality of "best selected" copper, however, was very uncertain, because it was obtained by a somewhat rule of the thumb method, and it frequently contained proportions of impurities, detrimental to the conductivity of copper, fully as great as those which had been introduced in the production of some more recent wires, such as phosphor-bronze. One of the most important impurities in "best selected copper" was arsenic, and arsenic and phosphorus were about equal in their detrimental effect on the conductivity of copper. He should like some additional information with reference to the statement that electro-deposited copper had not the same mechanical strength as ordinary refined copper. He hardly thought that the author meant to refer simply to copper in the condition in which it was deposited. Electricians would not attempt to make wires by depositing copper in that form, and he did not see why copper obtained by electrolysis should not be as strong as copper obtained by other methods, because by re-fusing copper in a reducing atmosphere, and then converting it into bar and rolling and drawing it in the ordinary way, it was subject to the same mechanical treatment, and was obtained in the same physical condition, so that, whether it had been originally reduced by electrolysis, or by chemical means, there could be no difference, as far as he could see, in the strength of a wire of a given purity.

With regard to galvanized wires, the author had pointed out that the durability of iron wire was maintained by galvanizing; and having described the method of treatment, he afterwards stated that the zinc with which the wire

was coated became oxidized when exposed to the air, and that, since zinc oxide was insoluble in water, the wire was protected by an impervious coat. There, as a chemist, he must join issue with the author, though the point was not a very important one. The truth was that oxide of zinc was by no means insoluble, but was actually soluble in soft water, like rain water, to such an extent, that galvanized iron could not be used with advantage as a material for the construction of tanks or conduit pipes where soft water existed, on account of zinc passing into solution in so considerable a proportion as to exercise an injurious medicinal effect upon the constitution. He thought that when galvanized iron wire was exposed to the air it became coated with a hard film of oxide, such as was formed when a sheet of lead, which was also an oxidizable material, was exposed to atmospheric influences. That hard film protected the metallic coating, and prevented further oxidation; so that the zinc itself was protected by the superficial coat of oxide, which was only very slowly removed by water, the zinc itself remaining as a protective to the metal until the atmosphere plus water found out some minute imperfection in the coating, and then, as soon as the smallest portion of the iron surface was exposed, the action established between the zinc and the iron led to rapid corrosion. That was why, even in the absence of the acid vapors to which the author referred as destructive to the metal in towns, galvanized iron, not only in the form of wires but applied to other purposes, was uncertain in regard to stability; and there could be no doubt that galvanized iron, though it had been very useful, was on that account a comparatively unreliable material.

He would next refer to an interesting form of conductor, of which those who had to construct military telegraph lines on active service had had considerable experience, namely, the so-called compound wire produced by coating steel wire with a copper sheath, which was soldered to the surface by drawing the steel wire through a bath of tin which acted as a cementing or soldering material. In that way, as the author had pointed out, a comparatively light and very strong wire of not very high resistance was produced, which presented at first sight important advantages as a conductor; so important indeed did they appear to be that the Royal Engineer authorities, finding the material when first tested to present such great advantages over ordinary iron, and even over copper wires in many respects, introduced it into the service in some recent campaigns. It was used in the Ashantee and Abyssinian wars, and afterwards in South Africa, and some was even sent to Egypt, though he believed it had been returned thence in the same condition in which it was sent out. The objections advanced against it even as recently as 1881, related simply to its being rather springy, and somewhat difficult to bend, but on the other hand it was found free from the liability to kink, so that the one defect was counterbalanced by the other advantage. But after the material had been in store a few years, and issued again for a special trial at Aldershot, it was found that when attempts were made to put up a line upon which some strain was brought to bear, the wire broke in many points; indeed it broke down utterly, and this was due to the effect pointed out by the author, namely, that there existed here and there minute imperfections in the building up of the wire, which, admitting the access of water and air, had established a corrosion of the steel wire and brought about the destruction of the material which at first sight presented such important advantages. There was one other disadvantage, namely, that when the wire had been roughly used there was a tendency of the outer sheath to peel off and injure the hands of operators handling it, and to be objectionable in many ways. It was for those reasons that the wire, which had been somewhat extensively used in the service, had been discarded.

The last class of wires to which Mr. Preece had referred were the bronze wires, the first of which was the so-called phosphor-bronze. Anyone first applying phosphor-bronze, correctly so called, to the production of a good conductor would be considered very short-sighted, for phosphorus was one of the elementary bodies about the most detrimental to the conductivity of copper that could possibly be used, ranking equal with arsenic in this respect. In some of the early

phosphor-bronze wires which he examined, having a resistance of about 49 or 50 ohms to the mile, there existed 0.22 and 0.18 per cent. of phosphorus. But, as the term "bronze" implied, there was always in those wires a certain proportion, but only a very small proportion, of tin. After referring to these new kinds of wires as alloys and as bronzes, the author stated that phosphor and silicium-bronze were so called, not so much because those materials were mixed with the copper, but because they were used in the preparation of the alloy, and there was no doubt that to a considerable extent that was the case. Phosphorus was undoubtedly a powerful deoxidizing agent; and as oxygen was one of the important enemies to the conductivity of copper, the introduction of phosphorus by removing the oxygen would increase the conductivity of the metal or of its alloy with tin. But it was almost impossible to produce a wire from a metal treated with phosphorus, without leaving some traces of phosphorus in the material; hence one could quite understand how so-called phosphor-bronze, though superior in point of strength to copper itself, was inferior in regard to conductivity, and was found to be very variable, because it would be exceedingly difficult to produce phosphorized bronze or phosphorized copper at different times containing precisely or approximately the same proportion of phosphorus. The latest form of bronze wire, and the one to which the author had directed special attention, was the silicium-bronze, to which Sir. F. Abel's attention had also been directed when visiting the electric exhibition at Vienna. He there saw the very thin wires now used for telephonic purposes. He had made some experiments with two samples of silicium-bronze wire brought from Vienna, and the results confirmed the statement of the author that the term silicium-bronze did not at all correctly represent the composition of the material; in point of fact it was not to be assumed that it need contain any silicium at all. In one wire which he examined the amount of silicium was 0.005 per cent., and in another there was not a trace of silicium. It should be observed that in the presence of tin, the proportion of silicium was very liable to be over-estimated, unless special precautionary measures were taken. The first wire was the coarser one used for telegraphic purposes, and it contained 97.75 per cent. of copper, and nearly 0.25 per cent. of tin. The finer wire contained a considerably larger proportion of tin, namely, 3 per cent., and although it was examined with great care, there was no evidence of the existence of silicium at all.

Those wires certainly possessed all the properties in regard to strength and powers of elongation and conductivity which were claimed for them; but although it was probable and perhaps certain in the case of one of them that silicium might have been in some way concerned in its production, there was no positive evidence that it derived any valuable quality from the employment of that material, unless it were that, by some special treatment, silicium became in the first instance alloyed with the copper, and by its own subsequent oxidation abstracted the oxygen contained in the alloy, thus removing an antagonist to the conductivity of the material. At any rate it would appear that the electrical qualities and the strength of the wires were chiefly due to the strength of the tin alloy used, and to the metal being employed in a hard-drawn condition. Both the wires were hard drawn when he received them. The tenacity of the coarser wire was from 300 lbs. to 325 lbs; its diameter was 2 millimeters, and its weight 100.5 lbs. per mile. After annealing, its tenacity was 190 to 200 lbs.; the finer wire had at first a tenacity of from 170 to 180 lbs., and when annealed, from 95 to 100 lbs. Although it was possible that silicium might have had something to do with their production, so minute a quantity as was detected by analysis in the one instance might have been purely accidental. It was possible that the chief merit of the process for producing the so-called silicium-bronze lay in the production of a wire consisting almost entirely of pure copper in a hard-drawn condition, but with a small proportion of tin, giving it increased strength. There could be no doubt that pure copper in the hard-drawn condition, with the addition of a small quantity of tin, was a very valuable conductor, and apparently the strongest conductor of

this class with which electricians were at present acquainted.

Professor D. E. Hughes perfectly agreed with Sir Frederick Abel with regard to the use of copper as a standard. His experiments on the molecular conductivity of copper neglected everything as to its chemical composition or its form, and simply regarded the structure of the material. He had a piece of pure copper given him by Prof. Chandler Roberts which he took as a standard, and the conductivity of some of the copper deposited electrically with a Daniell cell was 225, or more than double the standard of the Mint. That value did not perhaps represent the conductivity exactly, but he would say 50 per cent. higher value. It was found that if melted, it fell 50 per cent., and if re-melted it fell again. Whatever was done to change its molecular structure the conductivity fell. He therefore maintained that electricity-deposited copper was the very best form. If a wire could be actually deposited by electricity, it would be in the best form to conduct electricity. But that was not done. It was torn, and pulled, and twisted, and was no longer copper as it ought to be, but some changed conductor. The capabilities of any material in its pure state, and therefore the real standard, were not known. It could not, therefore, be said that the standard of copper was 100. Some experiments had been made by Professor Chandler Roberts and himself on bronze and tin alloy, and it was found that in gradually making the alloys there was a certain point at which a complete and sudden rise in value took place. He wished to ask the author a question with reference to conductivity. At present, in experimenting for conductivity, they used a Wheatstone bridge, and took the measure of the electricity after it had been flowing for a minute, or three or four or five minutes, till it had arrived at a stable condition. There was a period for telegraphic purposes which had been called in France the *période variable*, which was not measured, but which was very important for telegraphic instruments when making, say, one thousand contacts per second. There was a great difference between the results with the *période variable* and the *période stable*. If the Author in measuring his wires would use a rapid interrupter, with a Wheatstone bridge having contacts two or three thousand times in a second, he would get some very valuable information of the kind that he required. He did not want to know what it would conduct five minutes after the battery was put on, but what it would conduct during the first portion of the contact. He did not agree with the Author in regard to overhead wires. As an old telegraphic engineer he remembered that the wires were constantly broken. But why did that occur? The Author had himself shown that the zinc became oxidized, and that, that particularly occurred in smoky atmospheres. Perhaps he thought that London was not very smoky, and therefore was free from danger. It was stated in the Paper that there was danger, not to the inhabitants, but to the life of the wire itself, and for that reason an effort had been made to get compounds of wire, copper and steel, which gave great promise. It was thought to be an excellent wire at first, but after four or five years its defects were discovered. Indeed the history of telegraph engineering as a whole had been to the present time a history of success; but it had also its history of failures leading on, like the Atlantic cable, to a greater success. Electricians commenced with bad conductors and bad insulators, and then they gradually improved them; but they had not yet attained perfection. The Author now thought that the silicon wire was absolute perfection, and it had the appearance of it; but perhaps in four or five years his opinion might be changed. At present he had no hope for overhead wires except in that form. He had stated that only two persons out of four hundred thousand killed by accident in thirty years had died from injuries received from overhead wires. The wires, however, had not been up during the whole of that time, having increased very rapidly of late years. But the danger from the wires was not at the beginning, it was when they were getting old and shaky; and at such time he confessed he would rather be out of London than in it. It was true that, thirty years ago, Germany, as well as England, had tried underground wires, failure being the result; but this was in the early period of telegraphy, and sufficient care was not taken in the manufacture of the cables. Since then, owing to the rapid extension

of submarine telegraphy, great experience had been gained, so that the insulation of an underground wire was far better than that of aerial lines. The German Government, after a series of exhaustive experiments, decided upon the trial of a direct underground line from Berlin to Cologne, the success of which had led to a rapid extension in all directions, there being already some 15,000 miles of underground wires. At first their electricians had some difficulty in working these lines at high speed; but in a very short time, by the adoption of the necessary electrical conditions of contacts, reversed currents, and polarized relays, they had been enabled to work their high-speed instruments with far more regularity than was possible with the constantly deranged aerial wires. After mature consideration, the French Government had also lately put their main lines underground, having some 7,000, miles which would be increased as rapidly as the finances would allow. In Paris as well as in London the telephone companies put their wires overhead; and when he was at the Paris Congress he said it was a great pity that such a beautiful city be disgraced by overhead wires; that it did not much matter, perhaps, what was done with London, but that there ought to be at least one city free from the evil. All the overhead wires were afterwards taken down. The telephone people protested and declared that the telephones would not work, and that they could not get over the induction. They were, however, forced to put their wires underground, and it was now stated that they were working better than in any other country. Berlin as well as Paris had suppressed all aerial lines in the city; and as the German and French electricians had vanquished all electrical troubles, he had confidence that the Author would equally solve the problem for England.

Mr. J. Sivewright, C. M. G., thought there could be no question as to the importance of the subject of the Paper. He could not speak from the point of view of a scientific man, or a manufacturer of telegraph wire, but he could relate his own experience as a practical man who had to do with electrical conductors, and to whom the objections to the present form of conductor had been forced home nearly every day during the last seven or eight years; and he could from that experience bring forward facts which would go far to support the Author's view as to the extreme desirability of adopting some other form of electrical conductor in preference to iron wire, at all events for aerial lines. He wished to look at the subject from the point of view of a colonial telegraph engineer, because his experience had been drawn from the colony of South Africa, with whose telegraph engineering he had been connected during the period he had named. One of the main items of expense in that colony was transport. It was almost incredible for an Englishman living in a thickly-populated country, and with ample means of conveyance at hand, to appreciate the enormous difficulties in regard to transport in a new country. It might be sufficient to say that the Coal Measures of South Africa were lying practically dormant, and it was found cheaper to import coals from Newcastle than to get them out of the bowels of the earth 100 miles from the sea-coast. Again, tens and hundreds of thousands of acres of splendid arable land were lying waste, and wheat could be imported cheaper from South Australia or from the Peruvian and Chili coasts than it could be brought from the place where the African lands were lying fallow. The cause of the difficulty was transport. The same difficulty applied to the telegraphic engineer in the constructions of his lines. If a lighter form of wire were introduced having the same electrical qualities as the iron wire employed at the present day, the transport difficulty would be to some extent overcome. It was not so much the actual saving in the expense between a coil of copper and a coil of iron wire of the same electrical conductivity, although that was considerable; the great point was that the iron wire in telegraph construction was practically the pivot round which the other elements, as it were, revolved. It was what might be called the "independent variable," according to the variations of which all the other materials employed in telegraph construction would also vary. A lighter telegraph wire meant a lighter insulator. Less surface was exposed to the insulator, and consequently a smaller insulator could be used, because there was less leakage. And not only was there less leakage, but in regard to electrical storms, the difficulties which

had to be faced were correspondingly diminished. A lighter insulator meant a lighter pole; in fact all the plant of a telegraph line would get proportionately diminished in weight according as the gauge of wire was reduced, and with a reduction in weight followed a reduction in transport, so that a very great saving was effected. The coils of iron wire would be easier to handle, and there would be increased speed in the erection of the wire, attended with diminished cost. As to the question of joints, every one concerned in the maintenance of telegraph lines knew what a bugbear joints were. Whether the wire was copper or phosphor-bronze, or silicium bronze, as long as telegraph engineers in the Colonies got light, hard, durable, non-expansive, elastic wire, they did not care. They could get longer coils of it which could be run out to the extent, probably, of 600, 700, or 800 yards, but they were obliged to confine themselves to 500 yards (100 lbs. being about the average weight of the coils); not that manufacturers could not supply longer coils, but that length was found most convenient for handling. If they could dispense with a large number of telegraph joints, they not only saved in that way, but the maintenance became a far easier matter. Those were arguments which, from the colonial telegraph engineer's point of view, he brought forward in favor of reducing the gauge in telegraph wires. One objection that had been brought against the use of copper was that being of greater intrinsic value than iron, it would be more likely to be stolen. That was a specious argument at first sight, but Europeans, at all events, who were inclined to thieve would turn their attention to something more portable and valuable, and less likely to be detected, than the telegraph wire; while the aboriginal had a superstitious and wholesome dread of the wire, so that, in times of peace at any rate, he was hardly likely to meddle with it. Until within the last two years, the South African native respected the telegraph during the war, but that respect had now gone, and amongst the difficulties of telegraph maintenance the possibility of the wire being cut and taken away had to be faced. Still he thought that a native, if he had the option, would prefer iron wire during the war to copper, because it could be more easily turned into slugs or bullets for his gun. With regard to the effects of galvanizing, he was not opposed to the process; nor would he express any opinion as to its value in countries where the same climatic conditions existed as in England. But he might mention that in South Africa a wire treated as he had described in a bath of oil was erected at least fifteen years ago; it had no galvanizing, but although they had had some splendid specimens erected since, he knew of no better wire than the one to which he had referred. He had examined a considerable proportion of its length within the last twelve months, and he could not detect any flaw or mechanical fracture. It was ordinary soft wire, and had stood well. It was in a dry climate, with comparatively little moisture, with no smoke, and with none of the chemical causes which would affect ordinary wire. What had been said by the Author as to the necessity of rigid inspection almost amounted to a truism, at least he hoped it would be accepted as such; because there was probably no branch of science in which the old proverb was more applicable, "A stitch in time saves nine," than it was in regard to the selection of telegraph materials—not only the wire but all other requisites. Perhaps it required the experience of finding, 300 or 400 miles from the seaboard, insulators open, bolts missing, porcelain gone, iron bases fractured, and telegraph wire breaking in the workman's hands, to realise the enormous importance attaching to a rigid inspection of telegraphic materials. There was not only the value of the wire, but every one knew that if a workman had good material he would make a good job, and if he had bad material he was likely to slur over it. In his opinion, therefore, any administration that neglected so vital a consideration would be guilty of an act that was not only suicidal but criminal.

Professor A. K. Huntington thought it might be of interest if he gave a few figures with regard to four specimens of silicium-bronze wire which he had recently examined. They consisted practically of nothing but copper, with the exception of a small portion of silicon and tin. In the first coil there was a percentage of 0.099 of silicon, and 0.079 of tin. In the second coil the silicon was 0.117, and the tin 0.0017. In the third coil, silicon

0.1105, tin 0.014. In the fourth coil, silicon, 0.0917, tin 0.099. In the second and third coils the amount of tin was so small as to be well within experimental error, so that he was not prepared to say whether the coils really contained tin or not. From the examination of the specimens there was sufficient evidence to lead to the supposition that a certain amount of tin was present, at any rate in two of them. Whether that tin was simply an impurity derived from the ore, or whether it was the residue of tin which had been introduced during the manufacture, he was not prepared to say, as it was impossible to arrive at any conclusion on that point from a chemical examination of the wire. Silicon appeared to be present, and taking into account the supposed process of manufacture, there is no reason to doubt the existence of a certain amount of it. He had mentioned these particulars as bearing out, to some extent, the results given by Sir Frederick Abel, but with some differences in regard to the amount of tin. With reference to the introduction of silicon, he had succeeded in introducing large quantities of that material into copper, and, in some cases, with a very remarkable effect. As to the influence of arsenic on the conductivity of copper, that, of course, was a substance which was one of the greatest culprits in destroying conductivity. But there was another which the author had not noticed, namely, bismuth, which he thought had even still greater effect than arsenic in reducing the conductivity of copper. One of the countries to which the author had referred as supplying pure copper, Australia, had ores which contained an appreciable, and, in some cases, a considerable, amount of bismuth; and as the copper was often sent in ingots, there was liability to trouble with the material so obtained; because, although the bismuth could be removed without difficulty in the "best selecting" process, due to the relative affinities of copper and bismuth for sulphur, yet in refining, owing to the copper having greater affinity for oxygen than bismuth, it was not practicable to remove the bismuth merely by oxidation, so that if much were present the quantity could be reduced but slightly. That which was removed, so far as he could make out, was due to volatilization. Now, as the copper received from Australia had not been subjected to the "best selecting" process when in a state of regulus, it followed that it would contain any bismuth originally present in the ore. He had been told by a very large manufacturer that some copper which he had received from Australia, giving by analysis 99.67 per cent. of copper, gave a very bad conductivity—something like 30 as against 90 or 100. The result had been traced to the presence of bismuth. He had found, on further inquiry, that if there was more than 0.05 per cent. of bismuth present in copper its conductivity was seriously reduced.

Mr. D. Pidgeon said that the author had mentioned only to condemn the compound conductors which had been made both in England and America, and he had condemned equally those of the past and of the present. He did not rise to gainsay this, but simply to bring before the members some examples of the compound conductors now being made in America, and to say a few words with regard to the method of plating in use there. He had had an opportunity during the last spring of passing through the manufactory belonging to the Postal Telegraph Company of New York, at Ansonia, in Connecticut, a concern which was making the same wire as that already laid between New York and Chicago. The works were originally erected by Messrs. Wallace and Farmer, of Ansonia, the well-known electricians, for the purpose of carrying out ideas which originated with Mr. Farmer, but they had passed into the hands of the Postal Telegraph Company rather more than a year ago. The works occupied a space of 250 feet square, and there were in the building two hundred and fifty plating vats, which were supplied with current by twenty-three dynamos, driven by two engines, each of 300 H. P. It would give some idea of the amount of current supplied to the vats if he stated that he saw a carbon $\frac{7}{16}$ inch in diameter and 10 inches long deflagrated in the course of a few seconds by a shunt so small that its abstraction from the general current could not be noted in the results of the plating. The plating vats were wooden troughs 20 feet long and 2 feet 6 inches either way. Over each plating trough there lay longitudinally a horizontal cop-

per shaft about 3 inches in diameter, from which there hung, like rings from a stick, the coils of wire which were to be plated—as many of them as could be accommodated in the tank, the spires being separated by slips of plate glass, so as to prevent their contact. The balance of the coils hung outside the tank over the end of the shaft. Upon rotation, the coil of wire was screwed slowly through the electrolytic bath, and, after plating, hung again from the spindle, as the unplated wire did at the other end. This operation was repeated three times, the result being that 4,000 lbs. of copper were deposited daily upon 8 miles of wire. He held in his hand a piece of the compound conductor which had been thus three times screwed through the electrolytic bath. It was 0.214 inch in diameter, had a resistance of $1\frac{3}{4}$ ohm per mile, and a tensile strength af 2,700 lbs., of which the steel contributed 1,700 lbs., and the copper 1,000 lbs. This wire was the same as that through which telephonic speech was readily heard between Chicago and New York, as readily (as he had been informed by a gentleman who listened to it) as if the length had been no greater than that of a room. It was also the wire upon which ten simultaneous messages had been sent—five each way—by means of the well-known Gray harmonic arrangement. It might be said that the wire was very expensive, if only 8 miles a day could be produced by the expenditure of such a force as he had mentioned. But the process did not stop at that point. It had been found that the cohesion between the central steel core and the copper envelope was so great that it might be passed through the ordinary wire-drawing apparatus, and the core and the envelope would be reduced together. He exhibited a wire which had been produced from the one he had already shown. This was 12-wire gauge, outside diameter, while the steel core was 18 inch Birmingham wire gauge, and on examination it would be found that the steel core was perfectly central, with the copper surrounding it equally on all sides. Here, then, was a wire the exact equivalent, electrically speaking, of No. 4 iron wire, the largest now used in telegraphy. It could be produced at the rate of 32 miles a day, and the cost, therefore, was one quarter that of the other. If that conductor came into use it would be, in the first place, because its cost was so much diminished by the fact that it could be wire drawn, and in the second place, because the wire drawing gave to both wires a considerable increase in their tensional strength, and at the same time secured the conductor against the action of those atmospheric influences which the author had mentioned in his complaint of previous compound wires. This wire, although a compound one, was as capable of withstanding the attacks of the atmosphere as that of any wire drawn from homogeneous metal. He had a specimen of the joint which was employed in the wire extending between Chicago and New York. It was a copper ferule slightly flattened, and tinned by immersion. Into it had been thrust the ends of two wires, and the whole then dipped in a bath. Economically, the wire which he exhibited was the best which the Postal Telegraph Company had yet produced; but he was inclined to doubt whether, even taking into consideration the fact that plated wires could be four or six times increased in length, they could compete with the homogeneous wires of which the author had shown such extraordinary examples.

Professor Chandler Roberts thought there could be no question that pure copper was the best material to employ, because it was well known that a very small quantity of alloying metal caused the curve of conductivity of copper to fall rapidly; and it appeared to him that any increase of tenacity that might attend the union of copper with any other metal, not excepting silver, was dearly bought by the sacrifice of conductivity resulting from alloying the copper, and, as the electrician must have copper as pure as he could get it, any improvement in metallurgical processes for the extraction of copper from its ore assumed considerable importance. There were some facts connected with the electro-deposition of copper which had not been prominently noted in the discussion. He did not think that the scale on which the copper was now deposited electrolytically was quite appreciated. There were two works on the Continent which produced annually at least 500 tons of copper, and there were two works in this country that were being fitted with dynamo ma-

chines that would enable them to deposit copper at the rate of about 60 tons per week. He did not think it was quite understood that nearly pure copper could be thus obtained from very unsatisfactory materials. To take an extreme case, there were before him some specimens containing several per cent. of arsenic, and yet, by solution and precipitation, an excellent variety of copper had been obtained from similar specimens. The author seemed to fear that electro-deposited copper did not possess the same tenacity as ordinary copper; but statements had recently been made in the continental scientific journals, especially by Austrian authorities, showing that electro-deposited copper possessed a very high ductility and considerable tenacity. At any rate, the copper was free from metallic impurities, so that even if it had to be melted the metallurgist had only to contend with the question of dissolved cuprous oxide, which, after all, was a very small matter, because it could be so easily dealt with. Copper was now electrolytically precipitated in bars, rolled directly into rods, and drawn into wire, which found a ready sale at remunerative prices; and it must be remembered that against the extra cost of the solution and precipitation of the copper by electricity there was a handsome set-off, in the shape of the precious metals recovered from the crude metal. He thought, therefore, that the question might be safely left to metallurgists, who would have no difficulty in supplying the electrician with pure copper at a remunerative rate. The author had asked him to say a few words about the deposit of iron by electrolysis. It was well known that the late Professor Jacobi and Dr. Klein, of St. Petersburg, had taught how to deposit iron of great purity, and with considerable facility. That iron, he was sure, would not compete for electrical purposes with the extraordinary soft and pure varieties of iron which could now be produced by ordinary metallurgical means. The author had alluded to the effect produced by silicon in alloy with copper, and it had been stated that $\frac{9}{100}$ per cent. of silicon might be retained by copper. He should like to mention, because he did not think it was very clearly understood, that silicon had an extraordinary effect on many of the alloys of copper. The ordinary alloy of gold and copper containing 90 per cent. of gold fused at about 940° Centigrade, and, if it contained only $\frac{15}{100}$ per cent. of silicon, its melting point was so much reduced that a strip would bend and fuse in the flame of a candle. Hence it was that the presence of a minute quantity of silicon might be of the greatest importance in modifying the physical constants of pure copper.

He spoke with very little knowledge of the ordinary methods of electrical testing, but he did not think that the extreme delicacy of the induction-balance of Professor Hughes was quite recognized. He had some specimens of copper, which in regard to analysis were identical, and yet when disks of each sample of metal were treated in precisely the same way, mechanically and thermally, they showed a wide difference when submitted to this beautiful instrument, which would be a powerful ally in future, both of the electrician and the metallurgist. The principal point, however, to which he wished to direct attention was, that the metallurgist could supply the electrician with pure copper at a reasonable cost.

Mr. W. Carson desired to say a few words with regard to the effect of the presence of manganese, even in small percentages in conductors, upon the conductivity of the material. He had obtained two samples of puddled iron, from each of which he had made a number of tests. The first sample was from a highly manganiferous pig, with 6 per cent. of manganese. The second contained 3 per cent. of manganese. On being puddled, made into rods, and drawn into wire, the highly manganiferous pig produced an iron containing 98.871 per cent. of metallic iron, and 0.49 per cent. of manganese. The other sample of iron containing 3 per cent. of manganese gave 98.89 per cent of metallic iron in the wire, and only 0.184 of manganese, yet the mile-ohm resistance had risen to 5921.8. Under those circumstances he hardly thought that the Author was justified in laying the whole blame upon the manganese. He did not think that the manganese had much to do with the result.

Mr. J. Thewlis Johnson said the Author had shown the general improvement in the conductivity of copper wire, and had intimated that the improvements in iron wire had been forced on the makers,

who had not sufficiently availed themselves of the services of the chemist. In 1857 a relative of his, with the late Dr. Calvert, made a great many chemical experiments on pig iron, especially as to the changes in pig iron when being converted into wrought iron for wire purposes. The notes were published in the "Philosophical Magazine," in 1857, but the pecuniary results had been very small. Since then some of his friends had, like himself, taken a great deal of pains in conducting chemical experiments, but as far as his own results were concerned they had not been very considerable, and he had come to the conclusion that no iron wire could be made giving a less resistance than what was at present obtained. The difficulty of the iron-wire manufacturer had been to produce a material which would yield certain mechanical and electrical tests. The specifications recently drawn up were a great improvement on those existing twenty years ago, and the examinations were conducted on a rigorous and fair system. He thought it was generally admitted in the trade that manufacturers all knew what wire would give certain results, and the examining officer in making his tests soon found whether he would be able to pass the wire or not. When he had made a few tests he knew pretty well that if the remainder of the wire was of the same character it would either be all passed or all rejected. No one more than the Author had impressed upon wire manufacturers the necessity of endeavoring to improve the conductivity of iron. In season and out of season he had urged it upon them, and the result was that they were now all producing an iron which gave, ton for ton, a better average of conductivity or a less resistance than was obtained twenty years ago. But he wished to direct attention to the fact that while it was perfectly true that the iron wire used in England had decreased in resistance from about 15½ ohms in 1873 to 11¼ in 1883, low resistance wire had been a regular article of commerce long previously. He knew that in 1862 some 2,000 miles of wire were sent from England to the French Telegraph Administration, and it was identically the same as that now used by the English Post Office. In the specification of the French Telegraph Administration in 1862 there was no stipulation as to the conductivity of the wire; but it was stipulated that the wire should be manufactured in a particular way, which gave certain high mechanical tests, and also the conductivity tests which the Post Office now demanded. He could give many other instances, but he would only mention the line crossing the continent of Australia, erected in 1871. It was an unfortunate thing for the credit of England that the introduction of the conductivity test in the specifications, although advocated so long by the Author, did not first take place in England, but in America, by the Western Union Telegraph Company. He hoped the members would not leave with the impression that the days of iron wire as an electrical conductor were numbered. He had listened with great interest to the remarks on the process of depositing copper on steel, and he had been astonished by the statement that during the process of drawing wire when the copper was deposited on the steel the diameters of the steel and the copper were reduced equally. But for that statement he should certainly have doubted the fact. He believed that in practice it would be found that the deposited copper-coating would occasionally break in the process of drawing, and further, that as wire when drawn down became harder, and had to be annealed before the process could be repeated, a difficulty might arise in annealing a compound wire composed of steel and copper. The experiments with phosphor-bronze wire and compound wire, according to the Author, had not resulted satisfactorily, and there were only two other conductors, both of which were so expensive that economy compelled them to be used with a very small diameter. It was asserted that No. 14 copper wire, costing £87 a ton, was as efficient a conductor as No. 8 iron wire, costing £20, and that, mile for mile, it was not more expensive. That might be so, but he questioned whether it would be found as economical in practice. He thought that when it was scattered all over the country a good deal would be stolen. At Vienna there had been a large exhibit of silicium-bronze, the cost of which he was told was £162 a ton. It appeared to him that it would make a very charming toy line. It was never used till November 1881, when the first quantity was sent by the French

manufacturer to the Austrian Telegraph Administration for an experiment. He had seen no statistics as to its life. In India, monkeys often sat on the wires, and in the Colonies the birds flew against them, and he did not see, under such circumstances, how telegraph wires were to be maintained if they had only the diameter of pins and needles. Whatever conductors were employed, he thought they ought to have a good substantial diameter if the lines were to be maintained for any length of time.

Mr. A. J. Bolton exhibited some samples to show the process of manufacturing copper wire. The Author had referred to the rapid strides which had been made in improving the quality of conductors for electric currents, but these had also been greatly improved in form. It was often a great advantage to the electrical engineer to have the conductors of great length, and that object had now been accomplished. In 1850, when Mr. Charlton J. Wollaston, the electrical engineer of the experimental cable laid between Dover and Calais, came to his office with the order for the copper wire for the core of the cable, he was imperative that it should be made in continuous lengths to weigh about 30 lbs. in each piece. At that time, the only wire produced in copper of that size weighed about 4 lbs. in continuous length; and the foreman who was sent for to receive instructions, when he heard what was required, said, "Does the man think I am a fool?"—so impossible did he consider its production. At the present time continuous lengths were commonly made, with copper wire of the same diameter, weighing 70 or 80 lbs. The Author had stated that conductors for cables and electric light mains should be constructed with the purest copper producible. That object had been attained, and the samples on the table tested over 99 per cent. by Matthiessen's standard. With regard to aerial lines there might be some question. In his own works it had been found that in attempting to improve the tensile strength by introducing any foreign substance into the pure copper there was a loss of conductivity. The 14-gauge hardened-copper wire with high conductivity gave a breaking-strain of 340 lbs., and a resistance of only 8 ohms to the mile; the weight per mile was 103 lbs., and the cost about £4. A wire, 15 gauge, which had a resistance of $10\frac{3}{4}$ ohms per mile, had a breaking-strain of 255 lbs., and the cost was only 65*s.*—about the same as that of ordinary iron telegraph wire 0.171 size.

It would be seen from the table of the Author's experiments with silicious bronze that the 0.081 wire, with a resistance of $8\frac{1}{2}$ ohms per mile, gave only about an equal breaking strain to that of hardened copper of the same gauge, and the cost was about £6 per mile. It appeared, therefore, that hardened wire of high conductivity answered all the ends, and the breaking strain was a very good one, 340 lbs. being sufficient for all purposes. The objection to the introduction of phosphorus or other materials was, that results were never uniform; but with wire of high conductivity the results were always exactly the same. When silicon was introduced conductivity was wanting. The Author's next requirement was a low inductive capacity. That, he believed, would only apply to cables or insulated wires placed underground. Next, that the conductors should expose to wind and snow the least possible surface. Of course the lower the resistance the less the diameter of wire necessary to pass the same current, and therefore the wire of high conductivity would seem best to accomplish that end. The last requirement was that the wire should be practically indestructible. In that respect he thought that copper had everything in its favor. He might instance the case of a wire that had been more than twenty years over his own works; it had been constantly used for the passing of electric currents, and it had not altered in its conductivity or in its diameter during that period. As to coating steel wire with copper, and then drawing it down to make a conductor, reducing the diamater both of the steel and the copper, he too was much astonished. In his own works it was a common thing to put a steel mandrel inside a copper tube, and to draw the tube down; but the mandrel always remained the same diameter. He could hardly understand how the result that had been stated could be possible. To get wire of high conductivity it was essential that the ores, or the copper bars imported from Chili should contain as few alloys as possible, as then there was not much oxidizing required in the refin-

ing process. The copper was cast in large bars (of one of which he held in his hand a section). These were rolled into long strips like the specimen exhibited, and then passed through a series of circular steel cutters, which cut them longitudinally into narrow pieces, each of which was passed edgeways through grooved rolls, forming a nearly circular bar of copper, which was subsequently drawn down to wire of the required size. The process was different from the manufacture of iron wire, which was not slit but rolled down into a thin rod from a large bar. He also exhibited some specimens of hardened copper wires which had been subjected to different tensile strains, showing the diminution that had taken place in size, but they generally secured a breaking-strain of 340 lbs., which was found to be practically sufficient.

Sir Frederick Bramwell, Vice-President, said it appeared Mr. Bolton, like Mr. Johnson, was surprised that the two metals in a steel wire, coated with copper, when drawn should draw uniformly, and in support of his doubts had referred to the fact that, if a steel mandrel were put inside a copper tube, there was no elongation of the mandrel when the two were drawn together. That was perfectly true; but it should be remembered that in that case there was no metallic attachment of the mandrel to the tube. He wished to remind the meeting of a cognate instance in rolling—that when lead and tin were cast together in two thicknesses, to make Dobb's metal—it was formerly alleged that these two metals would not roll out uniformly; but, as a matter of fact, in whatever proportions they were cast—3 to 1, or 4 to 1—the rolled-out sheet showed the same proportion, although the metals were so dissimilar in their powers of yielding under the roll.

Mr. James Rock said he should like, as representing a company which manufactured both phosphor bronze and silicium-bronze, to say a few words on the subject under discussion. With reference to the uniformity of manufacture of alloys of copper, especially with silicon and phosphorus, it was part of the process of his company to manufacture those metals in strictly uniform proportions, and he could answer for the uniformity of the products as well as Mr. Bolton could for that of the copper which he had produced of such excellent quality. The French manufacturer of silicium-bronze, who was also the inventor, supplied large quantities to the French and other Continental Governments, and he guaranteed and produced it of certain degrees of conductivity and tensile strength. So far from silicium bronze being at present only a toy, on the Continent it was interfering largely with the use of iron wire for telegraphs. That was not the case in England, because the material was comparatively new. The analyses of Sir F. Abel and Professor Huntington confirmed the analyses in his own possession of similar alloys. There was, however, an apparent discrepancy with regard to the quantity of tin in the specimens. It was part of the process of manufacture that the proportions of tin and silicium should be adapted to the special uses for which the wire was intended. They accordingly produced two special kinds of electric conductors, one of high conductivity for telegraphs, and one of lower conductivity, but much greater strength, for telephones. The wire for telephones was largely used in England. It had very great tensile strength—as great as that referred to by the Author in connection with the telegraph wires for the Mumbles. It had similar properties to those wires, but a much higher conductivity; instead of 20 per cent., it had from 36 to 40 per cent. The apparent discrepancy between Sir F. Abel and Professor Huntington was probably due to their having analyzed examples of different constitution, one the telephone wire, and the other the telegraph wire. It was possible to produce silicium-bronze of different degrees of conductivity and of tensile strength. If electricians and engineers would only say what amount of strength and conductivity they required, the proportions could be adjusted accordingly. The product was a very valuable one, and the analysis of one specimen should not be taken as representing silicium.bronze generally.

Mr. Frederick Smith observed that the manufacturers of iron wire had not failed to make use of the services of chemists in endeavoring to improve that material. It should be borne in mind that the manufacturers of copper had a very dif-

ferent material to deal with at the outset, and the same advance therefore ought hardly to be expected from iron-wire manufacturers. Great progress, however, had been made, and he thought that the resources of civilization were not yet exhausted even in the improvement of iron or steel wire. He had been testing some samples of an English made steel wire, which gave as high a degree of conductivity as those of any Swedish charcoal iron he had tested, together with a much greater breaking-strain, and a higher degree of torsion. The six samples yielded the following results: Diameter 209, resistance, 8.13 ohms; diameter 208, resistance, 8.79 ohms; diameter 208, resistance, 7.98 ohms; diameter 209, resistance, 7.23 ohms; diameter 209, resistance, 7.74 ohms; diameter 209, resistance, 7.98 ohms. The samples were all tested in the bright hard state previous to galvanizing. After galvanizing, the improvement would be about 0.3 ohm per mile in each case. That was practically a new material. All who had worked for the specification for which the wire was used would know that a practically new material had to be made in order to meet the requirements. Instead of taking a material that already possessed a high degree of conductivity, the manufacturers had to take a material that gave a very great degree of resistance, and to bring it up to a high degree of conductivity; and they could only do that by making use of the services of chemists. With reference to the adoption of copper and phosphor-bronze or silicium-bronze, it should be borne in mind that a telegraph wire had a double function to perform. If it was simply a conductor and had only to carry the current, the wire with the highest degree of conductivity would undoubtedly be the best to employ; but the wire had not only to carry the current, it had to carry itself; it had to be out in all weathers, over very long distances, through all kinds of country, and it had to encounter all kinds of risks. It was necessary, therefore, that it should have a certain amount of bulk. Much had been said about wires breaking down, but if wire was used of the kind that had been so highly praised, he thought the number of breakages in all parts of the country would be greatly increased. He had recently tested a sample of hard-drawn copper wire, and had found that the mechanical properties were inferior; it would not stand wrapping and unwrapping round its own diameter without breaking. That was a test which all hard wires ought to stand. The material bore only about $\frac{1}{2}$ per cent. elongation, which an inspector would put down as nil, after allowing for the fracture itself. The breaking strain also was very slight, and it would only allow fourteen twists in 6 inches. The size of wire that he tested was 0.81, about No. 14 W. G., which was about one-quarter of the weight of iron wire of the same conductivity. Instead, therefore, of being only four times the cost, as might be expected, it was eight times the cost, consequently the cost of the line made of copper would be twice that of a line made of iron wire, so far as the wire was concerned. It was also exposed to great risk from the slightest motion of the posts, and any substance thrown against it caused it to break immediately. In hot countries, where perhaps the wire would be most used in consequence of the great cost of transport, the results of changes in temperature might be very serious. The sun was very hot by day, and the nights were often cold, and the wire would not possess sufficient ductility to stand such changes in temperature, which might cause it to snap. Mr. Johnson appeared to think that in the manufacture of compound wire, the steel would not be reduced at the same time as the copper or to the same extent. He might be permitted to remind him that it was the custom amongst wire-drawers to draw wire coated with tin, and both were reduced at the same time without the tin being removed by contact with the draw-plate. If so soft a metal as tin could be so treated he thought that copper would bear the same kind of treatment.

Mr. J. H. Greener had been connected with telegraph works for nearly forty years, and most of his time had been spent in erecting lines and supervising stores for different administrations. Meanwhile great improvements had been made on all sides. He was glad of the opportunity of speaking of iron wire before it became a thing of the past, which seemed to be the hope of the manufac-

turers of copper and bronze. Twenty years ago iron wire weighing 600 lbs. to the mile would not bear the strain of 1,000 lbs. without breaking. In the present day, with the same wire a breaking strain of 2,000 lbs. could easily be obtained. The Post Office specification required a wire of very fine material, almost pure iron, because, working as they did duplex and quadruplex, the authorities wanted high conductivity. The specification for the India Office required for a wire of the same size 350 lbs. more breaking strain. The extra breaking strain had been a great bugbear to the wire manufacturers. They could easily give the 350 lbs. additional breaking strain, and also the capability of sustaining fifteen twists in a length of 6 inches, but when the conductivity test was also applied they had a very difficult task to perform. It had been accomplished, but to effect this the aid of the chemist had to be called in, because the wire manufacturers found that it would not pay to go on with the rule of thumb methods previously in use. He had with him some tests of the wire made by different firms during the past year. In the wire made by No. 1 firm, the average breaking strain was 2,196 lbs.; No 2, 2,123 lbs; No. 3, 2,150 lbs.; No. 4, 2,195 lbs. This uniformity was astonishing. Those results had not been achieved without a great deal of hard work, worry, and anxiety on the part of the manufacturers, who, in carrying out the specifications, had always been willing to render every possible assistance. No doubt they had often thought him a great nuisance, but they had certainly helped him in every possible way.

Mr. Killingworth Hedges desired to say a few words on the effect of powerful lighting currents through a copper conductor. It was most important that engineers who had to do with electric lighting, and local authorities who proposed to purchase expensive copper cables and lay them down to distribute electricity in their districts, should be certain that the passage of a powerful current had no effect on the conductivity of the wire. He had noticed, as mentioned by the Author, that wires taken from dynamo machines, especially those which had an alternating current passing through them, became brittle. He had thought it might be interesting to ascertain whether there was any change in an ordinary commercial cable which had been carrying a current of electricity for some time, and he had for this purpose tested a cable through which a current had been flowing for nine months, say about sixteen hundred working hours. The electromotive force was 1,000 volts, the size of the cable 7 strands, No. 16 B. W. G., and the current 10 amperes. He tested the resistance carefully, and compared it with that of a cable of similar design which had never been used, and he could find no difference. He then had the fracture examined microscopically, and he could detect no signs of brittleness. The cable had only been working a comparatively short time, and the current therefore was very small in proportion to the area, about one-fourth of what the maximum current might have been as allowed by the Board of Trade, 2,000 amperes per square inch of section. If a larger current had been used there would probably have been some heating, as Dr. Matthiessen, in his contribution to the Royal Society,* had shown that if heating took place in a copper cable of a certain degree of impurity, there was an alteration in its conductivity, and he had quoted the case of a very impure piece of copper, which increased in resistance 0.064 per cent., after being heated to 100° Centigrade for three days. Dr. Matthiessen's experiments only went as high as 100° Centigrade, but Mr. Hedges thought he would go as high as he could in heating various wires of pure metals and alloys by a current of a secondary battery, and the results were stated in the annexed table.

The first column showed the material used; the second, the resistance before heating; the third, the decrease of resistance after heating; and the fourth, the approximate temperature as nearly as it could be obtained. The experiments tended to show that the pure metals underwent no change in resistance after being heated twenty-four hours; but those containing some commercial impurity decreased in their resistance and increased in conductivity. The decrease was very small and was most noticeable in No. 3, the tin alloy, to which he desired to

* Phil. Trans. 1864, vol. 154, p. 167.

Materials.	Resistance. Before Heating.	Decrease after 24 Hours.	Temperature. Fahrenheit.
No. 1. Tin wire	0.815	0.003	390°
No. 2. Lead	0.835	{ 0.005 in 3 hours }	590
No. 3. Tin alloy	0.870	0.005	490
No. 4. Copper	0.810	No change	1,900
No. 5. Tin-foil	0.860	"	400
No. 6. Albo alloy	0.835	"	1,200

draw attention. The experiment in that case was only carried on for three hours, by which time the conductivity had increased 7 per cent. He could not carry it on longer because the alloy melted, probably by the decrease in resistance allowing a larger amount of current to pass. This alloy (tin and lead) was well known in the form of solder, which was largely used for jointing electric-light wires. It was dangerous to rely on solder alone because it would be softened by the passage of the current if there was any heat caused by a slightly imperfect joint, and an action would then go on which he thought had a tendency to reduce the metals into their constituent parts, so that by degrees the two wires would come a little apart, an arc would be formed, and the joint destroyed. All joints for electric lighting purposes ought to be made mechanical under considerable pressure, the solder should only be used to keep away the air. It would be interesting if the Author would give his experience of the joints used by the Post Office, also whether there had been any variation in resistance after they had been employed a long time. The question of joints was most important for electric lighting. Dynamo machines afforded a most economical method of transforming mechanical work into electricity, and the problem of using the current of electricity and distributing it successfully appeared to him to be in the cost and the efficiency of the conductors and their joints. Now it was required in a perfect conductor that the current in its passage should develop no heat until it arrived at the lamps, where the heat would be utilized in the form of light. The Author had suggested a possible variation of resistance due to temperature of 20 per cent., between summer and winter. He hardly thought that would be the case in England. In some climates perhaps there might be that amount of variation if overhead wires were used for electric lighting purposes, but if they were placed underground he did not think they would be subject to as much variation in temperature as were ordinary gas and water pipes, in that they would be surrounded and carefully insulated by some material which not only was an insulator of electricity but a non-conductor of heat.

Mr. T. H. Blakesley considered that in view of the large outlay which would probably take place in conductors for the distribution of electricity for electric lighting or other purposes, the Author had passed rather hurriedly over the law of economy which Sir William Thomson was the first to suggest. He ventured to recall the attention of the Institution to that point, first because of its great importance, secondly because the Author had somewhat imperfectly quoted the law, and thirdly because that economy was in practice very rarely carried out, it being generally thought advisable to save present outlay at the expense of future current expenses. The problem of course, was analogous to the one which engineers constantly had to encounter in pumping through hydraulic mains. If the main was contracted too much, there was a saving in the expense of pipes but a loss in the current expense of pumping. There were two forms of the law usually given, one that which had been stated by the Author, and the other asserting that the current should be always proportioned to the sectional area of the conductor. Both statements were somewhat imperfect, and were, moreover, very often misapplied. Sir William Thomson arrived at a result

giving about 322 amperes to the square inch of conductor of copper, when the price of the copper was £70 a ton and 5 per cent. interest was allowed on the outlay, and the time during which the current flowed was one-half, or twelve hours a day. The late Sir William Siemens, in his address before the Society of Arts, arrived at the value of 390 amperes per square inch, taking £90 as the value of copper per ton and 7½ per cent. interest on the outlay, and one-third of a day, or eight hours in twenty-four, as the time of working. All these changes tended in the same direction. Now 390 did not materially differ from 324, and even one of the alterations which he made was sufficient to account for the difference. The reason why the divergence was so small was that he had put the cost of energy at 12d. per 10 Board of Trade units, which most people thought very high. He had used what would correspond more to the price of energy than to the prime cost; but in that problem no doubt the prime cost was the thing that should be taken into consideration. But whatever the values of these quantities, Sir William Thomson's law was only applicable to conductors where the expense of the conductor varied with the weight of it. No doubt in telegraph wires that was approximately the case; but in the distribution of electricity on a large scale for electric-lighting purposes, or for the transmission of energy, the conductors were insulated, and probably underground, and on comparing the price of a bare conductor with its cost when highly insulated, it would be found that the price of the insulation was in excess of that of the conductor itself, for ordinary conductors, say of a ¼ square inch section, and that the extra expense of insulation did not vary anything like according to the section of the conductor, but more nearly as the diameter of the wire, or as the virtual diameter in the case of a bundle of wires. That would greatly modify the law as usually quoted for a proper economical system. One outcome of the calculation in this case was that there was no longer the constancy between the current to be carried, and the sectional area to carry it, which was so often quoted. Another outcome was that the number of amperes that might be put through a square inch was much higher than that given by Sir William Thomson or by Sir William Siemens. He had ascertained from the prices of a well-known manufacturer, that, with a conductor thoroughly insulated with gutta-percha and covered with jute and tape in sections ½ square inch, and employed for twelve hours in twenty-four throughout the year, there ought to be 566 amperes per square inch passing through it; for less sections of conductor more could be put through a unit of section. This rate per square inch increased sensibly, though not largely, as the section got smaller.

Mr. W. H. Preece, in reply, observed that Sir Frederick Abel questioned the difference said to be found between the conductivity of hard-drawn and soft copper; but his own figures showed that it was 2 per cent. in favor of the latter, and this corroborated the accepted figure. He still maintained that iron manufacturers had not sufficiently brought to their aid the talents of the chemist. At the present time they absolutely did not know what was the conductivity of pure iron. Professor Chandler Roberts had kindly offered to supply him with a piece of pure iron, but it was not certain that he had a piece to supply. Indeed, he did not know that a piece of pure iron had ever been seen. If anybody would supply electricians with absolutely pure iron, they would be delighted; at present they did not know what resistance it gave. It was true that Professor Hughes, with his exquisite little instrument, had told some curious stories about the internal arrangement of molecules, and he was prepared to assert that certain specimens were 225 times better than certain other specimens. He had not mentioned, however, how to obtain iron of sufficient purity to make perfect magnets and perfect wires. On the question of iron bars and copper wires, Professor Hughes had suggested that the probability was that after five years' experience copper wire would be rejected, just as compound wire had been. In England the requisite five years' experience had been obtained; and electricians certainly had not arrived at the conclusion that copper was a better conductor for overground purposes than iron, without long experience and very rigid practical tests. They now had copper wire, not in pounds or in miles, but in hundreds

of miles scattered over the country, and the result of their experience had been to show that for certain purposes (he did not say for all) copper had a greater superiority over iron than some of the speakers would be inclined to believe. Mr. Johnson appeared to think that copper would be stolen, but that had not been the result of past experience. As to monkeys climbing upon wires, those animals, like iron-wire manufacturers, had increased in intelligence. In the early days of telegraphy they did climb upon the wires and break them down, but they did not do so now. Perhaps the difference was due to the fact that the first telegraph wires were made of thick iron rods, while the more recent wires were much finer, and the finer they were the less likely monkeys might be to perform gymnastics upon them. He was sorry that Professor Hughes differed from him on the subject of overhead wires. He believed that all electricians were agreed upon one point, that whatever the merits or demerits of overhead wires, they were better adapted for high-speed apparatus and general telegraph work. There could be no doubt that if a wire were extended between London and Manchester it would be commercially sixteen times worse underground than above ground; and to try to force an Administration like the Post Office to put its wires underground, because of some imaginary danger, was as absurd as it would be to try and force every railway company to tunnel underneath the roads instead of crossing them by bridges. It had been said that overhead wires were dangerous, but, as he had asked before, where was the danger? There was much more danger in opening trenches. The number of accidents from the latter cause very far exceeded those from falling wires. As to the question of economy, those who had to spend the money were, he thought, the best judges on that point. His remarks, however, applied to outlying districts. The parish of Wandsworth, for instance, wanted a fire telegraph and a police telegraph; the Post Office authorities wished to put the wires overhead, and the Wandsworth Board tried to force them to put them underground: the postal authorities had resisted, and the matter was now before a court of law. The opposition raised in many of the outlying districts against overhead wires was, he considered, a senseless proceeding; it meant additional expense, and it did not remove danger. Who cared about the appearance of wires in a country district? No doubt many of the streets in London would be considerably beautified if some of the numerous wires were removed; his remarks, however, did not apply to the city of London, but only to outlying districts. What local authorities needed was power to control the erection of overhead wires, not necessarily power to forbid their erection. In all large cities and towns the Post Office put the wires underground, not to diminish danger, nor to improve appearances, but for convenience and economy; they had even an underground line between Liverpool and Manchester. Wherever it was necessary the lines were put underground, but they did not intend to put them there unless it was absolutely necessary, and they were not to be forced to do so by any absurd mania on the part of the local authorities. The important question of joints had been raised by Mr. Hedges; but there was one that had been settled long ago by telegraphists, it was, that the telegraphic joint as now constructed was perfect. In his long experience of thirty years, and he could appeal to those who could speak of a still longer period, the existence of a bad joint in a line properly constructed by an experienced man was absolutely unknown. He had seen, however, in lines used for electric lighting, most inefficient joints, and it was a matter of surprise that many of the electrically lighted public buildings had not been destroyed by the utterly unsuitable wires that had been employed. There had been serious accidents, and there would be more unless electric-lighting engineers took a little more to heart the lessons of experience on this point. He had been contented with quoting in its broadest sense Sir William Thomson's law, leaving the results to be worked out by those who wished to apply it, and who possessed the current prices of materials. The subject had been more fully worked out by Mr. T. Gray. He however agreed with Mr. Blakesley, that the number of amperes per sectional area which could be transmitted with safety and economy was greater than that given by Sir William Thomson and the late Sir W. Siemens.

EXAMINATION OF THE FORMULÆ USED IN CALCULATING THE PRESSURES IN STONE WORK.

By E. SHERMAN GOULD, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

In an article published in the April No. of this Magazine, I gave the two fundamental formulæ used in determining the maxima elementary pressures upon the base of a dam or other structure of masonry as follows:

$$(1) \qquad p=2\left(2-\frac{3u}{l}\right)\frac{P}{l}$$

$$(2) \qquad p=\frac{2}{3}\cdot\frac{P}{u}$$

These formulæ are of the utmost importance; they constitute the foundation of the entire theory of high masonry dams. They were given in the article named without demonstration—their general acceptance by the highest mathematical and engineering authorities seemed to render anything beyond their mere enunciation unnecessary. Enquiries and criticisms which have since come to my notice, however, suggest that some further examination of them may prove of interest.

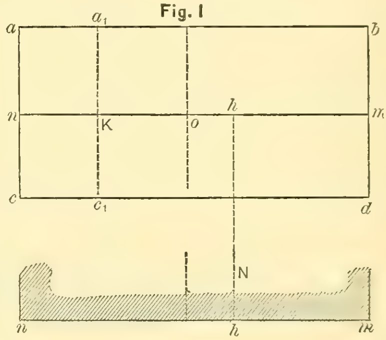
For this purpose I cannot do better than present a translation of Debauve's investigation and discussion of these formulæ, adding a note here and there which may be useful to those who approach the subject for the first time.

Mons. Debauve treats of the matter in his work upon stone bridges (10th fascicule of the "Manuel de l' ingénieur"), under the head of abutments. I proceed to translate, commencing at page 109 of the above.

PROBLEM.—Being given a homogeneous mass of masonry (Fig. 1) with vertical sides and a rectangular horizontal section *abcd*, the base being pressed by a vertical force N, the point of application *h* of which is situated upon one of the axes of symmetry of the rectangle, it is required to determine the elementary pressure at any point of the rectangle, and particularly to determine that point at which such pressure is maximum.

NOTE.—*By "elementary pressure" is meant the pressure per square unit, expressed in any given standard of weight. Using French measures, the elementary pressure would be given in kilos. per square meter, which would, however, be generally reduced to kilos. per square centimeter. Using English measures, it would be given in lbs. per square foot, usually reduced to lbs. per square inch. By "one of the axes of symmetry" is meant the line nm* (Fig. 1) *which divides the rectangle into two equal parts.*

Fig. 1



In chapter I. of his "Cours de méchanique appliquée," Mons. Bresse solves completely the above problem by a consideration of the centers of percussion. We cannot here present this elegant and interesting investigation. The results reached by Mons. Bresse are given at page 62 of his treatise, and are as follows:

1° When the point of application *h* of the vertical pressure N is such that its distance *oh* from the center of the rectangle is less than one third of the half axis *om*, if we represent the ratio $\frac{oh}{om}$ by n, and the surface of the rectangle *abcd* by S, the maximum pressure will occur at the edge *bd* of the rectangle, and this pressure per unit of surface will be given by the formula

$$(1) \qquad p=\frac{N}{S}(1+3n)$$

2° If on the contrary the ratio $\frac{oh}{om}$ is greater than one third, the maximum pressure still occurs at the edge bd, but its degree is given by the formula

$$(2) \qquad p=\frac{\mathrm{N}}{\mathrm{S}}\cdot\frac{4}{3\,(1-n)}$$

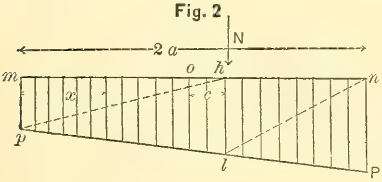
In the first case the entire surface $abcd$ sustains pressure; when the ratio n becomes $\frac{1}{3}$, the entire surface is still pressed, but the pressure is *nil* at the extreme edge ac; in the second case, (when n is greater than $\frac{1}{3}$), if we take $mk=3mh$ the pressure will be *nil* beyond a_1c_1 and will go on increasing from a_1c_1 to bd.

NOTE.—*It will be seen that the above formulæ are really identical in value with those quoted at the commencement of this article, though under a different form. To establish their identity, it is only necessary to replace* N, S *and* n *by their equivalents* P, l *and* $\frac{l-2n}{l}$. (bd *being supposed to be equal to unity*, S$=l$).

But a simple demonstration may be given of the preceding formulæ.

Let us represent the length of the rectangle by $2a$; by p and P the pressures at m and n (Fig. 2), and let x be the dis-

Fig. 2



tance separating m from any given point in the axis mn, and c the distance between the point h of application and the center o of the axis.

Under the influence of the pressure N, the base mn is more or less displaced (or compressed). We assume that it does not become distorted but remains a straight line. We assume, moreover,—and this is in accordance with the laws of elasticity—that at any given point the elementary pressure is measured by the degree of displacement or compression. Thus at m the pressure is measured by mp.

In virtue of these hypotheses, which experience in a measure confirms, we may calculate the compression by imposing the condition that all the elementary pressures have a resultant equal and opposite to N. For this it is necessary:

1° That the sum of the elementary forces such as mp,—a sum represented by the area of the trapezoid mnpP,—should be equal to N. This furnishes the equation:—

$$(1) \qquad \mathrm{N}=(\mathrm{P}+p)a$$

2° That the sum of the moments of the elementary forces about the point h should be algebraically equal to o. (Fig. 2).

The sum of the moments of the forces to the left of h is equal to the moment of the area of the trapezoid $mhpl$, and that of those to the right of h, is equal to the moment of the area of the trapezoid nhPl. The vertical hl is equal to

$$p+(\mathrm{P}-p)\frac{a+c}{2a}$$

NOTE.—*Put* $hl=p+z$. *Then* z *is given by the proportion*

$$\frac{z}{\mathrm{P}-p}=\frac{a+c}{2a};\ z=(\mathrm{P}-p)\frac{a+c}{2a} \textit{ and } hl$$

is found to be as above.

The altitude of the left hand trapezoid is $(a+c)$, and that of the right hand trapezoid is $(a-c)$. Putting the moments of the two trapezoids in equation, we obtain:

$$(2) \ p.\frac{a+c}{2}.2.\frac{a+c}{3}+\left(p+(\mathrm{P}-p)\frac{a+c}{2a}\right)\times \times\frac{a+c}{2}\cdot\frac{a+c}{3}=$$

$$=\mathrm{P}\cdot\frac{a-c}{2}.2.\frac{a-c}{3}+\left(p+(\mathrm{P}-p)\frac{a+c}{2a}\right)\times \times\frac{a-c}{2}\cdot\frac{a-c}{3}$$

NOTE.—*It will be observed that the two trapezoids are divided into four triangles by the lines ph, ln and it is the sum of the moments of these triangles which is given in* (2).

From equations (1) and (2) the following values of p and P are derived, in terms of N.

$$(3) \qquad \mathrm{P}=\mathrm{N}\frac{(a+3c)}{2a^2};\ p=\mathrm{N}\frac{(a-3c)}{2a^2}$$

NOTE.—*To obtain these equations, put* A$=(a+c)$ *and* B$=(a-c)$. *Then by re-*

duction, simplification and substituting the value of $P=\frac{N-ap}{a}$ *from* (1) *we have;*

$$2a\,(3A^2a-A^3+aB^2+AB^2)\,p=$$
$$=N\,(4aB^2+AB^2-A^3)$$

Replacing A *and* B *by their values, effecting the necessary calculations and reducing, we have* $p=N\frac{(a-3c)}{2a^2}$ *as above.*

The value of P *is then obtained by substitution in* (1).

From (3) we see that the maximum pressure occurs at the edge of the rectangle nearest to the point of application of the pressure N.

Since the above calculations refer to a rectangle *abcd* of which the width *bd* is supposed to be unity, we have $S=2a$. If now we put $\frac{c}{a}=n$ the value of P may be written under the more simple form given by Mons. Bresse;

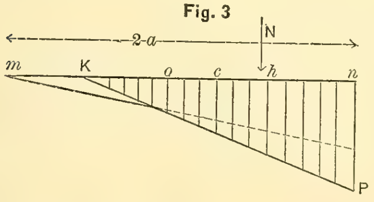
$$P=\frac{N}{S}\,(1+3n)$$

Let us now see how the elementary pressures vary as the force N changes its point of application; c may vary from o to a.

For $c=o$, we have $P=p=\frac{N}{S}$. That is, the pressure is uniformly distributed over the whole base.

As c increases, P also increases, and p diminishes. When $c=\frac{a}{3}$, $p=o$; so that for $c>\frac{1}{3}\,a$ there is an area mk (Fig. 3) of the

Fig. 3



rectangle which sustains no pressure, and this area is easy to determine, for it is only necessary to take $nk=3nh$. At k the pressure is nil, as it is also for all the surface situated to the left of k, and the pressure increases progressively from k to n, where it becomes maximum.

$$\text{For } c=\frac{a}{3};\ P=2\frac{N}{S}$$

that is, the pressure is double that which occurs under an uniform distribution.

For $c>\frac{a}{3}$, we have (Fig. 3) $nk=3\,(a-c)$ and the area of the triangle knP which represents the sum of the elementary pressures, should be equal to N, whence we have the relation:

$$N=\frac{P}{2}\,.\,3\,(a-c),\text{ or } P=\frac{2}{3}\frac{N}{(a-c)}$$

Put $\frac{c}{a}=n$, and remembering that the surface of the rectangle forming the base is measured by $2a$, we may write the value of P thus:

$$P=\frac{2}{3a}\cdot\frac{N}{1-n}=\frac{4N}{S}\frac{1}{3\,(-n)}$$

When the force N is applied directly at the edge, that is when $c=a$, the pressure at this point becomes infinite.

The above constitutes the investigation of Mons. Debauve. Before offering any comments upon it, I will add some observations which he makes upon the resistance to crushing of stone, so excellent and practical that they cannot but prove of interest to engineers.

After giving the usual tables of the strength of different varieties of stone, Mons. Debauve says:—

But too much confidence must not be placed in the above figures, for they take no account of a very important factor and one as yet but little studied, namely the influence of the *size* of the specimens tested upon their resistance.

Dupuit in his treatise upon bridges, gives the following results, based, it is true, more upon reasoning than actual experiment:

It has been found, he says, that with equal surfaces, the resistance increases as the section approaches a circle, and that it decreases with the height, particularly if the specimen be divided into several layers. We can easily understand that when several prisms bear upon one another, the pressure is unlikely to be transmitted uniformly over the whole surface. It may happen, therefore, that some parts will be strained beyond their resistance before a pressure is reached

which, if uniformly distributed, could have been safely sustained.

While upon this subject we will remark, that so far experiments have only been made with uniform pressures extending over the whole surface of the prisms tested. In actual practice however, it often happens that only a portion of the surface sustains pressure. In such cases, can we consider the surface pressed as being isolated, and as liable to be crushed by a pressure that would crush it if it were isolated? We do not think so, although it is customary to so consider it. As we have already stated, crushing only takes place as an effect of lateral dilatation, and when there exists an obstacle to such dilatation, the resistance to crushing is thereby increased. This is a principle well understood in practice. Thus, we ring the head of piles to prevent their splitting, and put iron bands around certain supports destined to bear heavy loads. Let us suppose for instance that a cube of stone five centimetres high crushes under a load of 10,000 kilos, or 400 kilos per square centimetre. We certainly should not conclude from that fact that crushing would ensue if we placed an iron column with a base of 25 square centimetres, in the middle of a block of the same stone, a square metre in area, and loaded it with a weight of 10,000 kilos. It is quite certain that we should find the resistance enormously increased.

The proposition that, under all circumstances, whenever the pressure reaches the limit of resistance crushing ensues, leads to absurd consequences. Thus, if we should calculate the area of the point of a well sharpened pointing tool, we would conclude that it would pass through granite like a needle through a piece of cloth, and that stone could be cut with a razor. The figures we have given (referring to table) only relate to pressures covering the whole surface of the specimen tested. If the pressure is local and only bearing upon certain points, the resistance increases in proportion as these points are farther from the sides, but we know nothing of the manner in which the resistance acts under these circumstances, and for lack of data follow incorrect assumptions.

Instead of multiplying experiments upon all the known stones used in building, we should endeavor, first to ascertain how resistance varies with the dimensions of the specimens tested, the pressure being uniformly applied; and secondly, how it varies under local pressures, applied to different parts of the surface.

Crushing is due, as Dupuit remarks, to the lateral expansion of the stone, the compressed parts endeavoring to escape at the sides, where they find no impediment to so doing. When the pressure becomes so great as to destroy the cohesion of the fibers, they burst asunder, and crushing ensues.

Any cause which opposes this lateral expansion will have for effect the retardation of the crushing of the material, by annulling more or less of the tendency to spread. Mons. Pelletreau in a recent paper corroborates the above statement by demonstrating the following proposition:

Other things being equal, a prism of stone resists crushing in proportion to the degree of friction existing between its base and the surface upon which it stands.

In another part of his volume, Mons. Debauve gives instances of very heavy pressures sustained by the pillars of some noted buildings. Thus:

	lbs. per sq. inch
The pillars of the Invalides	213
The pillars of St. Peter's at Rome	230
The pillars of St. Paul's, London	272
The pillars of dome of the Pantheon	414
The pillars of tower of St. Méry	414
The pillars of Church of Toussaint at Angers	627

These are certainly enormous charges, much greater some of them, than any builder would knowingly incur at the present day. No doubt the architects of these edifices never gave the question of crushing a thought, but simply carried up their structures according to artistic design, and let the pressures be what they would. Mons. Debauve does not state whether the above pressures occur at the bottom of the foundations, under ground, or in free air. This would unquestionably make a great difference. I do not know what the elementary pressure upon the piers of the Brooklyn bridge is, but it must be something enormous.

It should be remembered too, that the sub-foundations of this structure consist of a heavy layer of *timber*, resting upon concrete, so the whole of the great weight rests on wood instead of stone. No doubt when the substructure is carried down to

such a great distance below the surface, the strong hold which the encasing material takes of its sides very materially lessens the weight actually resting on the bottom. Unquestionably pressures may be admitted below the surface, which would be dangerous if sustained by portions of the structure deprived of lateral support; besides it is certain that at great depths below the surface, the nominal pressures do not really exist, the weight being largely sustained by the adherence on the sides. For this reason, the sides of buried foundations should be built vertical, and not spreading out below ground.

Let us now return to Debauve's examination of Bresse's formulæ.

It would no doubt be unwise to attempt a thorough investigation of the problem without a careful study of Mons. Bresse's own solution of the given problem by the method of centers of percussion. I have not been able to find this latter author's work in the Astor library, and am therefore ignorant of his process of demonstration, but, as stated at the commencement of this article, his results have been generally accepted, and pass current among the most eminent European authorities without challenge. This is saying a great deal.

As regards Debauve's demonstration, if we admit his assumptions, the results follow naturally. Let us see what these assumptions are. He assumes (as does Bresse) a homogeneous mass. That is a mass, all the parts of which are uniformly bound together, so that any local pressure is disseminated throughout the mass. Thus, a local pressure acting vertically downward, does not bear wholly upon that portion of the base directly under it, but is transmitted to the other parts of the base as well. There can be no difficulty in accepting this assumption, for it is not a scientific abstraction, but a practical essential of good workmanship.

His next assumption is, that the base, while undergoing compression, is not distorted, but remains in a straight line. With this, we must also couple the tacit assumption that the mass rests upon an unyielding base, or one which is practically unyielding. As the structure, in the case of high dams, must stand on bed rock, we cannot refuse to admit this. Even if we consider the pressure in the upper courses of the work, we should still find, I think, that the upward reaction of the rigid base was operative through the intervening material.

The rigidity of the base being admitted, we seem forced to grant the absence of distortion. The only assumption which still remains to be examined is, that compression is proportional to pressure. This can be readily conceded, and it would then appear that Mons. Debauve has rested his demonstration upon reasonable grounds.

It may be remarked that in the problem announced, the sides of the assumed mass are supposed to be vertical. It is difficult to see how this condition affects the results, and it is neglected by Debauve in the application of the formulæ to dams.

It will be observed that he introduces a distance, represented by x, (Fig. 2), of which no use is made in the demonstration.

One word may perhaps be usefully added upon the subject of compression. All building materials are more or less compressible, and all buildings undergo more or less compression from their own weight and from such exterior forces as they may be subjected to. In the case of masonry this compression takes place mostly in the mortar. But a point is sooner or later reached, when compression ceases, or else the whole structure would flatten out into a sheet of infinite thinness. The mass has then become incompressible. If the pressure still augments, another action takes place, namely, that of crushing. We may say that there are three distinct stages in the phenomena accompanying pressure applied to stonework. First, there is the compression due to the artificial and composite character of the mass considered as a whole. This consists in taking up the vacancies of the work, or in the settling of the structure to its bearings. Then comes the condensation, due to the natural compressibility of the materials when brought in actual contact with each other. This is no doubt slight when compared to the former contraction. The pressure still augmenting destruction of the cohesion of the material occurs; that is crushing and disentegration. These three actions may be going on simultaneously in different parts of the same structure; and we may have, according to circumstances, either the establishment of equilibrium, or destruction of the edifice.

BICYCLES AND TRICYCLES.*

By C. V. BOYS.

From the "Journal of the Society of Arts."

The subject of this paper is one of such wide interest, and of such great importance, that it is quite unnecessary for me to make any apology for bringing it before your notice. Exactly two months ago, I had the honor of dealing with the same subject at the Royal Institution. On that occasion I considered main principles only, and avoided anything in which none but riders were likely to take an interest, or which was in any way a matter of dispute. As it may be assumed that the audience here consists largely of riders, and of those who are following those matters of detail, the elaboration, simplification, and perfection of which have brought the art of constructing cycles to its present state of perfection, I purpose treating the subject from a totally different point of view. I do not intend, in general, to describe anything, assuming that the audience is familiar with the construction of the leading types of machines, but rather to consider the pros and cons of the various methods by which manufacturers have striven to attain perfection, As a discussion on the subject of this paper will doubtless follow—and I hope makers or riders of every class of machine will freely express their opinion, for by so doing they will lend an interest which I alone could not hope to awaken—I shall not consider it necessary to assume an absolutely neutral position, which might be expected of me if there were no discussion, but shall explain my own views without reserve.

The great variety of cycles may be grouped under the following heads:—

1. The Bicycle unmodified.
2. The Safety bicycle, a modification of 1.
3. The Center-cycle.
4. The Tricycle, which includes five general types:—
   (*a.*) Rear steerer of any sort.
   (*b.*) Coventry rotary.
   (*c.*) Front steerer of any sort (except *e*).
   (*d.*) Humber pattern.
   (*e.*) The Oarsman.
5. Double machines: sociables and tandems.
6. The Otto.

It is perfectly obvious that not one machine is superior to all others in every respect, for if that were the case, the rest would rapidly become extinct. Not one shows any signs of becoming extinct, and, therefore, it may be assumed that each one possesses some points in which it is superior to others, the value of which is considered by its riders to far outweigh any points in which it may be inferior. The widely varying conditions under which, and purposes for which, machines are used, and the very different degrees of importance which differently constituted minds attach to the peculiarities of various machines will, probably, prevent any from becoming extinct, Nevertheless, the very great advantages which some of these possess over others will, no doubt, in time become evident by the preponderance of the better class of machines.

The bicycle, which surpasses all other machines in simplicity, lightness, and speed, will probably, for these reasons, always remain a favorite with a large class. The fact that it requires only one tract places it at a great advantage with respect to other machines, for it is common for a road which is unpleasant from mud or stones to have a hard smooth edge, a kind of path, where the bicyclist can travel in peace, but which is of little advantage to other machines. Again, the bicycle can be wheeled through narrow gates or doorways, and so kept in places which are inaccessible to tricycles. One peculiarity of the bicycle, and to a certain extent of the center-cycle, is that the plane of the machine always lies in the direction of the resultant force, that the machine leans over to an amount depending on the velocity and the sharpness of the curve described. For this reason all lateral strain on the parts is abolished, and if we except the slipping away of the

* A paper read before the Society of Arts.

wheel from under the rider, which can hardly occur on a country road, an upset from taking a curve too quickly is impossible. This leaning to either side by the machine and rider gives rise to that delightful gliding which none but the bicyclist or the skater can experience. In this respect the bicycle has an enormous advantage over any machine, tricycle or Otto, which must at all times remain upright, and which must, therefore, at a high speed be taken round a curve with discretion.

The perfect and instantaneous steering of the bicycle, combined with its narrowness, counteract, to a great extent, the advantage which the tricyclist has of being able to stop so much more quickly, for the bicyclist can "dodge" past a thing for which the rider of the three-wheeler must pull up. In one other respect the bicyclist has an advantage, which, though of no real importance, has great weight with many people. The bicycle well ridden presents a picture of such perfect elegance that no one on anything else need expect to appear to advantage in comparison.

The chief disadvantage of the bicycle is the fact that a rider cannot stop for any purpose, or go back a little, without dismounting. For town riding, where a stoppage is frequently necessitated by the traffic, this perpetual mounting and dismounting is not only tiresome but wearying, so much so, that few bicyclists care to ride daily in town.

The position of the rider on a bicycle with respect to the treadles is by no means good, for if he is placed sufficiently forward to be able to employ his weight to advantage without bending himself double, he will be in so critical a position that a mere touch will send him over the handles. He has, therefore, to balance stability and safety against comfort and power; the more forward he is, the more furiously he can drive his machine, and the less does he suffer from friction and the shaking of the little wheel; the more backward he is, the less is he likely to come to grief riding down hill, or over unseen stones. The bicyclist is no better off than the rider of any other machine with a little wheel, the vibration from which may weary him nearly as much as the work he does. The little wheel as a mud-throwing engine is still more effective on the bicycle than it is on any tricycle, for in general it is run at a higher speed.

I now come to the usual complaint about the bicycle. There is a fashion just now to call it dangerous, and the tricycle safe. But the difference in safety has been much exaggerated. The bicyclist is more likely to suffer from striking a stone than his friend on three wheels, but then he should not strike one where the tricyclist would strike a dozen. Properly ridden, neither class of machine can be considered dangerous; an accident should never happen except it be due to the action of others. People, carts, cattle, and dogs on the road are liable to such unexpected movements, that the real danger of the cyclist comes from the outside; to danger from absolute collapse due to a hidden flaw in the materials employed, every one is liable, but the bicyclist more remotely than the tricyclist, owing to the greater simplicity of his machine. The bicyclist, though he has farther to fall in case of an accident from any of these causes, is in a better position than the tricyclist, for he is outside instead of inside of his machine; he can in an instant get clear. It would appear that many tricyclists consider accidents of the kind next to impossible, for in several machines the rider is so involved, that an instantaneous dismount without a moment's notice, at any speed, is absolutely impossible. There remains one objection, which, however, should be of next to no importance—the difficulty of learning the bicycle prevents many from taking to the light and fast machine, because they are afraid of a little preliminary trouble.

The chief objections to the bicycle, then, are the liability of the rider to go over the handles, the impossibility of stopping very quickly, and the inability to remain at rest or go backwards, and the difficulty of learning.

The first two of these are, to a large extent, overcome in the safety bicycles, but not without the introduction of what is in comparison a certain degree of complication, or without the loss of the whole of the grace or elegance of the bicycle. On almost all these safety bicycles the rider is better placed than on the unmodified bicycle, but though safer I do not think bicyclists find them compete in

speed, though, no doubt, they are superior in that respect to the tricycle. Though they do not allow the rider to stop without dismounting, the fatigue resulting from this cause is less than it is with a bicycle, owing to the fact that with the small machines the rider has so small a distance to climb. Of these machines, the "Extraordinary" leaves the rider high up in the air on a full-sized wheel, but places him further back and more over the pedals. The motion of these is peculiar, being not circular but oval, a form which has certain advantages.

In the Sun and Planet and Kangaroo bicycles, a small wheel is "geared up," that is, is made to turn faster than the pedals, so as to avoid the very rapid pedaling which is necessary to obtain an ordinary amount of speed out of a small wheel. In each of these the pedals move in a circular path, and their appearance is in consequence less peculiar than that of the Facile, which, in this respect, does not compare favorably with any good machine. The pedal motion on the Facile is merely reciprocating. Riders of machines where circular motion is employed, among them myself, do not believe that this reciprocating motion can be so good as circular, but I understand this view is not held by those who are used to it. Of course, the harmonic motion of the Facile pedal is superior to the equable reciprocating motion employed in some machines where speed is an object, especially with small wheels.

If I have overlooked anything typical in the modified bicycle class, I hope some one will afterwards supply the omission, and point out any peculiarities or advantages.

That very peculiar machine, the Centercycle seems to combine many of the advantages of the bicycle and tricycle. On it the rider can remain at rest, or can move backwards; he can travel at any speed around curves without an upset being possible; he can ride over brickbats, or obstructions, not only without being upset, but if going slowly, without even touching them. As this machine is very little known, a few words of explanation may be interesting.

In the first place, the rider is placed over the main wheel, as in the bicycle, but much farther forward. There are around him, on or near the ground, four little wheels, two before and two behind, supported in a manner the ingenuity of which calls for the utmost admiration. Turning the steering handle not only causes the front and rear pairs to turn opposite ways, but owing to their swivelling about an inward pointing axis, the machine is compelled to lean over towards the inside of the curve: not only is this the case, but each pair rises and falls with every inequality of the road, if the rider chooses that they run on the ground; but he can, if he pleases, arrange that in general they ride in the air, any one touching at such times as are necessary to keep him on the top of the one wheel on which alone he is practically riding. He can, if he likes, at any time, lift the main-weeel off the ground, and run along on the others only. The very few machines of the kind which I have seen have been provided with foot straps, to enable the rider to pull as well as push, which is a great advantage when climbing a hill, but this is on every machine except the Otto, of which I shall speak later, considered a dangerous practice.

Some of the objections to the bicycle to which I have referred were sufficient to prevent many, especially elderly men, from dreaming of becoming cyclists. So long as the tricycle was a crude and clumsy machine, there was no chance of cycling becoming a part, as it almost is, and certainly soon will be, of our national life. The tricycle has been brought to such a state of perfection, that it is difficult to imagine where further progress can be made.

Perhaps it will be well to mention what is necessary, in order that a three-wheeled machine may be made to roll freely in a straight line, and also round curves. At all times each wheel must be able to travel in its own plane in spite of the united action of the other two. To run straight, the axes of all the wheels must obviously be parallel. To run round a curve, the axis of each must, if continued, pass through the centre of curvature of the curve. If two wheels have a common axis, the intersection of the two lines forming the axis can only meet in one point. To steer such a combination, therefore, the plane of the third wheel only need be turned. If the axes of no two are common, then the planes of two of the wheels must be turned in

order that the three axes may meet in a point.

Not only does free rolling depend on the suitable direction of the planes of the wheels, each wheel must be able to run at a speed proportional to its distance from the point of intersection of the three axes, *i. e.*, from the ever-shifting center of curvature.

The most obvious way, then, of contriving a three-wheeler is to drive one wheel, steer with another, and leave the third, which must be opposite the driver, idle. The next in simplicity is to drive with one wheel, and steer with the other two, having one in front, and the other behind. So far, then, the single driving rear-steerer and the Coventry rotary pattern are easily understood. The evils of single driving minimised, it is true, to a large extent in the Coventry rotary, have led to the contrivance of means by which a wheel on each side may be driven without interfering with their differential motion in turning a corner. Three methods are commonly used, but as only two are employed on tricycles, I shall leave the third till I come to the special machine for which it is necessary. The most easy to understand is the clutch, a model of which I have on the table. If each main wheel is driven by means of one of these, though compelled to go forward by the crankshaft, it is yet free to go faster without restraint. By this means "double driving" is effected in several forms of tricycle. Differential gear, which is well understood, and of which there are several mechanically-equivalent forms, divides the applied driving power, whether forwards or backwards, between the main wheels, equally if the gear is perfect, unequally if imperfect. To understand the effect of the two systems of driving, and of single driving, let us place on grooves a block which offers resistance to a moving force. If we wish to move it, and apply our force at the end of one side, it will tend to turn round as well as move forward, and much friction will be spent on the guides by their keeping it straight. This is the single driver. If, instead of applying force at one side, we push the block bodily forward by a beam moving parallel to itself, then so long as the guides are straight no strain will be put upon them, even though one side of the block is resisted more than the other; if, however, the guides compelled the block to travel round a curve, then the power, instead of being divided between the two sides in such proportion as is necessary to relieve the guides of all strain, is suddenly applied only to the inside, and the effect is that of a single driver only. This is the clutch. Lastly, if the last-mentioned beam, instead of being pushed along parallel to itself, were pivoted in the middle, and that pivot only pushed, the same power would be applied to each side of the block, and no strain would be thrown on the guides, whether straight or curved, so long as the resistance opposed to the block on the two sides were equal; if, however, one side met with more resistance than the other, then the guides would have to keep the block straight. This is the differential gear. I have assumed that in the last case the force was applied to the middle of the beam; this corresponds to every evenly-balanced gear. In the gear employed by Singer, which is not evenly balanced, but which derives its good qualities from its simplicity, the same effect is produced as if the beam were pivoted on one side of the center, instead of on the center. Thus, though both sides are driven, one is driven more than the other. On the whole, there is no doubt that the balanced gear gives a superior action to the clutch, for except when the two sides of the machine meet with very different resistance, and then only when running straight, the clutch will not compare with the other. The clutch also gives rise to what is considered by most riders a grave defect, the inability to back treadle, while the free pedal, which is an immediate consequence, is considered by others a luxury. On the other hand, this same free pedal can be obtained on differentially-driven machines to which speed and power gear have been applied.

Of the relative merits of different forms of differential gear there is little to be said. Perhaps it will not be thought I am unduly thrusting myself forward, if I refer to a scheme of my own, in which no toothed wheels are employed, but in which two conical surfaces are driven by a series of balls lying in the groove between them, and jambed against them by a recessed ring. I have here a large wooden diagrammatic model, and a small working model in steel, which shows that

the new principle employed is correct, namely, that a ball while jambed is free to turn, or if turning is able to jamb. All Humbers, and most front steerers, employ differential gearing; in some front steerers the clutch of necessity is used.

Neglecting for the present the different modes of transmitting power from the pedals to the main wheels, it is possible now to consider the four typical builds of tricycle. The only advantage that a rider can find in a rear-steerer is the open front, so that in case of accident he can more easily clear himself of his machine; as I have already remarked, this power of instantly escaping seems to be considered by many as of no importance. In a rear-steerer which has not an open front, whether driven by a clutch or by differential gear, I fail to discover any good quality. The steering of a rear-steerer is so very uncertain, that such machines cannot safely be driven at anything like a high speed, because any wheel meeting with an obstruction will, by checking the machine, diminish the weight on the steering wheel just at the time when a greater weight than usual should be applied. It is for the corresponding reason that the steering of a front-steerer is so excellent; the more the machine is checked by obstruction, by back treading or by the brake, the greater is the weight on the front wheel. For shooting hills, or for pulling up suddenly, no machine of any kind will compare with a good front-steerer. In all respects it is superior to the rear steerer, if we except the open front, but against this may be set the fact that on many the rider can mount from behind, or can dismount in the same manner while the machine is in motion. Experience shows that the front-steerer is, for general excellence, safety, easy management, and light running, the best all-round tricycle that is to be had.

The Humber build, which departs less from the ordinary bicycle than any other, is far superior to all others for speed; it is, however, somewhat difficult to manage, for the steering is not only delicate, but critical, requiring constant care lest a stone or other obstruction should take the rider unawares, and steer the machine for him. The control which a skillful rider of the Humber has over his machine is wonderful; the elegance of the machine among tricycles is unequaled. So great a favorite is this form, especially among the better class of riders, that almost every firm have brought out their own Humber, each with a distinguishing name. The only improvement or change, whichever it may be, that has been made by others with which I am acquainted, is the triple steering, in which the hind wheel moves the opposite way to the others. The corresponding change in the bicycle was soon discarded; I do not know what advantage can result from the increased delicacy of steering here; I should have thought it delicate enough already.

One noticeable change in the front-steering tricycle, which has been largely made lately, is the substitution of central for side-gearing, in consequence of which bicycle cranks can be employed, instead of the cranked axle, with its fixed throw. This gives an appearance of lightness which the older types of machine do not possess.

I now come to that very difficult and all-important subject, the method of transmitting power from the body of the rider to the main axle. Next to the structural arrangement, this is most important in distinguishing one type of machine from another.

The first to which I shall refer is the direct action employed on the "National" and the "Monarch" tricycles. It is obvious that by having no separate crank shaft, much greater simplicity and cheapness, and less friction are attained, than can be possible when the extra bearings and gear generally used are employed. In this respect the direct action machines undoubtedly have an advantage, but an advantage of any kind may be too dearly bought, as it certainly is here. In the first place, the direct action can only be applied to a rear-steering, clutch-driven machine, or single driver, for if the wheels were not free to run ahead, it would be impossible to go round a curve. In the second place, the rider must be placed at such a height for his feet to work on the axle, that the machine of necessity is very unstable, and is likely to upset if ridden without great caution round a curve. Thirdly, to diminish as far as possible this last objection, miserable little wheels must be employed, which cannot be geared up, that is, made to travel faster than the treadles, and so be

equivalent to larger wheels. Therefore, though it is likely that at such low speeds only as it is safe to run such a machine, it may move more easily than a machine of a recognized type, and though direct action would undoubtedly be advantageous if it did not entail defects of a most serious order of magnitude, we may dismiss this at once from our consideration. It is true that in the "Monarch" a few inches of height are gained by the hanging pedals, but I question very much whether one machine is much better than the other.

The chain which is used on almost every make of machine cannot be considered perfect; it is, on the whole, a dirty and noisy contrivance, giving rise to friction where the links take and leave the teeth of the pullies; stretching, or rather lengthening, by wear, and, finally, allowing back lash, which is most unpleasant. In spite of all this it affords a convenient and reliable means of transmitting power, which is applicable to every type of tricycle except one.

Instead of a chain, an intermediate or idle wheel has been tried, but this has not been found advantageous. The intermediate wheel has been removed, and the crank and wheel pulley allowed to gear directly together, making reverse motion of the feet necessary, and possibly reducing friction.

The crank and connecting rod are employed in some machines. If there are two only, they must not be placed in opposite positions, but be fixed at an angle, so that there are times when each rod is under compression, a strain which delicate rods cannot stand. In the three-throw crank, employed in the matchless tricycle, this objection is obviated, for one, at least, is at all times in such a position as to be in tension. The objection to the crank is the fact that it weakens the shaft, and that it can only be used with a clutch, not with a differential gear.

The most silent, neatest, and cleanest driver, the one of which the working friction is least, is the endless steel band, so well known in connection with the Otto bicycle. This is not, as far as I am aware, employed on any tricycle, makers probably fearing lest it should slip. The Otto shows that it can safely be employed.

I have devised a scheme, of which I now show a model, which seems to me to be free from the objections which may be urged against other methods; but I, of course, cannot be considered in this respect a judge. Eccentrics are well known as equivalent to cranks, but if used in the same way, with a connecting rod, either fatal friction or enormous ball-bearings would be necessary. Instead of these, I connect two pair of equal eccentrics by an endless band embracing each, so that the band acts like a connecting rod without friction, and at the same time acts by its turning power as on the Otto, thus making two eccentrics sufficient instead of three, and carrying them over the dead points.

There is one more system of transmitting power employed on a few machines. In these a band or line passes over the circumference of a sector or wheel, and the power is directly applied to it. The motion of the feet in the omnicycle, and of the hands and body in the oarsman, is therefore uniform. There would be no harm in this if it were not for the starting and the stopping, which cannot be gradual and at the same time effective in machines of this type. For this reason a high speed cannot be obtained; nevertheless, these machines are better able to climb hills than are tricycles with the usual rotary motion, for, at all parts of the stroke—which may be of any length that the rider chooses—his driving power on the wheels is equal. The ingenious expanding drums on the omnicycle makes this machine exceptionally good in this respect, for increased leverage is effected without increased friction, which is the result of "putting on the power" in some of the two-speed contrivances.

Having spoken of the oarsman tricycle, I must express regret that I have not been able to find an opportunity to ride on or with the machine, so that I cannot, from observation, form an opinion of its going qualities. There can be no doubt that the enormous amount of work that can be got from the body in each stroke on a sliding seat in a boat must, applied in the same manner on the oarsman tricycle, make it shoot away in a surprising manner; whether such motion, when continued for hours, is more tiring than the ordinary leg motion only, I cannot say for certain, but I should imagine that it would be. The method by which the

steering is effected by the feet, and can with one foot be locked to a rigidly straight course, is especially to be admired.

There is much difference of opinion with respect to the most suitable size for the wheels of machines. Except with certain machines, this has nothing to do with the speed at which the machine will travel at a given rate of pedalling, for the wheels may be geared up or down to any extent that is made to turn more quickly or slowly than the cranks. This, the most suitable speeding, is a separate question, and must be treated by itself.

Large wheels are far superior to small wheels in allowing comfortable easy motion, a matter of considerable importance in a long journey. They are also far better than small for running over loose or muddy ground, for, with a given weight upon them, they sink in less, from the longer bearing they present, and this, combined with their less curvature, makes the everlasting ascent which the mud presents to them far less than with a smaller wheel. On the other hand, the large wheel is heavier, and suffers more from air resistance than the small wheel. For racing purposes a little wheel, geared up of course, is certainly better than a high wheel; for comfortable traveling, and in general, the high wheel is preferable. Though this is certainly the case, it does not follow that large wheels are worth having on a machine when there is already one little wheel. If the rider is to be worried with the evils of a little wheel at all, it is possible that any advantage which large wheels would give him would be swamped by the vibration and mud-sticking properties of the small steering wheel. One firm, in their endeavors to minimize these evils, have designed machines without any very small wheels; all three wheels are large, and a steadier and more comfortable motion no doubt results.

High and low gearing are the natural sequel to high and low wheels. Of course, the lower the gearing the greater is the mechanical advantage in favor of the rider when meeting with much resistance, whether from wind, mud, or steepness of slope. In spite of this, for some reason which I cannot divine, the machines with excessively low gear do not seem to obtain so great an advantage in climbing hills as might be expected. To make such a machine travel at a moderate speed only, excessively rapid pedalling is necessary, and the rider is made tired more by the motion of his legs than by any work he is doing. The slow, steady stroke by which a rider propels a high-geared machine is far more graceful and less wearying than the furious motion which is necessary on a low-geared machine. The height up to which the driving wheels are usually geared may be taken as an indication of the ease with which any class of machines runs. A rider on a low-geared machine can start his machine much more quickly than an equal man on one that has high gearing, and therefore in a race he has an advantage at first, which he speedily loses as his rapid pedalling begins to tell. For ordinary riding, the slight loss of time at starting is a matter of no importance whatever.

There are several devices which enable us to obtain the advantages of high and low gearing on the same machine, which at the same time give the rider the benefit of a free pedal whenever he wishes. On some single driving rear-steering tricycles the connection on one side is for speed, and that on the other for power, either being in action at the wish of the rider, or both speed and power combinations are applied on the same side. To drive with a power gear a single wheel only seems to me the height of folly; in my opinion no arrangement of this type is worthy of serious attention. Among the better class of machines there are three methods by which this change is effected—First, that employed on the omnicycle, to which I have already referred; secondly, an epicyclic combination of wheelwork which moves as one piece when set for speed, thus adding nothing to the working friction except by its weight, but which works internally when set for power, thus reducing to a small extent, by the additional friction, the gain of power which the rider desires; thirdly, a double set of chains and pulleys, each set always in movement, so that whether set for speed or power, there is rather more friction than there would be if there were no additional chains, but these are free from that increased friction due to toothed-wheel gearing, from which the epicyclic contri-

vances suffer only when set for power. There is much difference of opinion whether any of these arrangements are worth carrying, for perhaps nine miles, for the sake of any advantage that may be obtained in the tenth. It is on this account that the drums on the omnicycle are so excellent; whether expanded or not, there is, on their account, no loss of work whatever, for there is no additional friction. The subject of these two speed gears will, I hope, be discussed; it is one which, though not new, is coming more to the front, and about which much may be said.

Having now dealt with the means by which tricycles are made to climb hills more easily, I wish to leave the subject of bicycles and tricycles altogether for a few minutes, to say a few words which may specially interest those who are fond of trying their power in riding up our best known hills. The difficulty of getting up depends to a large extent on the surface and on the wind, but chiefly on the steepness. The vague manner in which one hill is compared with another, and the wild ideas that many hold who have not made any measurements, induces me to describe a method which I have found specially applicable for the measurement of the steepness of any hill on which a cyclist may find himself, and also a scheme for the complete representation of the steepness and elevation of every part of a hill on a map so as to be taken in at a glance. The force required to move the thing up a slope is directly proportional, not to the angle, but to the trigonometrical sine of that angle. To measure this, place the tricycle, or Otto—a bicycle will not stand square to the road, and therefore cannot be used—pointing in direction at right angles to the slope of the hill, so that it will not tend to move. Clip on the top of the wheel a level, and mark that part of the road which is in the line of sight. Take a string made up of pieces alternately black and white, each exactly as long as the wheel is high, and stretch it between the mark and the top of the wheel. If there are n pieces of string included, the slope is 1 in n, for by similar triangles the diameter of the wheel is to the length of the string as the vertical rise is to the distance on the road. This gives the average steepness of a piece sufficiently long to be worth testing, because an incline, only a few feet in length, of almost any steepness can be mounted by the aid of momentum.

There is only one process with which I am acquainted which supplies a method of representing on a map the steepness of a road at every part. Contours, of coures, show how far one has to go to rise 50 or 100 feet, but as to whether the ascent is made uniformly or in an irregular manner with steep and level places, they tell us nothing. Let the course of a road be indicated by a single line where it is level, and by a pair of lines where inclined. Let the distance between the lines be everywhere proportional to the steepness, then the greatest width will show places of intermediate steepness, the crossing of the lines, which must be distinguishable from one another, will show where the direction of the slope changes. Further, the size of the figure bounded by the two lines will show the total rise; a great height being reached only by great steepness or by great length, a large figure being formed only by great width or by great length. Those who are mathematically inclined will recognize here that I have differentiated the curve representing the slope of the hill, and laid the differential curve down in plan.

Having wandered off my subject, I must return to more mechanical things, and give the results of some experiments which I have made on the balls of ball bearings. There is no necessity to argue the case of ball *v.* plain bearings, the balls have so clearly won their case, that it would be waste of time to show why. Of the wear of the twelve balls forming one set belonging to the bearings of the wheels of my Otto, I have on a previous occasion spoken; I may, however, repeat that in running 1,000 miles, the twelve balls lost in weight only $\frac{1}{20.8}$ grain, or each ball lost only $\frac{1}{250}$ grain. The wear of the surface amounted to only $\frac{1}{158000}$ inch; at the same rate of wear, the loss in traveling from here to the moon would amount to only $\frac{1}{34.3}$ of their weight. I examined each ball every 200 miles, and was surprised to find that on the whole the wear of each, during each journey

varied very little. The balls experimented on were a new set obtained from Mr. Bown. I also had from him one ball of each of the following sizes 3, 4, 5, 6, and 7–16ths of an inch in diameter, as I was curious to know what weight they would support without crushing. As a preliminary experiment, I placed a spare $\frac{5}{16}$ ball between the crushing faces of the new testing machine at South Kensington, and applied a gradually increasing force up to 7 tons $9\frac{1}{2}$ cwt., at which it showed no signs of distress. On removing it I found that it had buried itself over an angle of about 60° in the hard faces, faces so hard that a file would not touch them. Those marks will be a permanent record of the stuff of which the ball was made. The ball itself is sealed in a tube, so that any one who is curious to see it can do so. Finding that the crushing faces were not sufficiently hard, I made two anvils of the best tool steel, and very carefully hardened them. These, though they were impressed slightly, were sufficiently good for the purpose. In the following Table are the results of the crushing experiments:—

$\frac{3}{16}$ ball at 2 tons 13 cwt. did not break, but crushed on removing part of the weight.

$\frac{1}{4}$ ball at 3 tons 15 cwt. did not break, but crushed on removing part of the weight.

$\frac{5}{16}$ ball at 4 tons 9 cwt. broke.

$\frac{3}{8}$ ball at 8 tons 6 cwt. did not break, crushed under another 120 pounds.

$\frac{7}{16}$ ball crushed before 3 tons, with which I was starting, had been applied. Examination showed that the steel bar of which it was made had been laminated.

These experiments do not tell much of importance; they are curious, and, perhaps, of sufficient interest to bring before your notice. The fragments are all preserved in tubes, and labeled so that anyone who likes to see them can do so.

Of the advantage which a machine which will collapse or fold up when desired, but retain its form on the road, offers in convenience, it is unnecessary for me to speak.

Of double machines, the Rucker tandem bicycle seems to me to be in every respect the best, but I should add that I speak only from imagination and not from experience. The independent steering, the impossibility of capsizing forwards or sideways, the position of the rider over his work, the absence of any little wheel with its mud-throwing and vibrating tendencies, combine to make a machine which ought to be superior in almost every desirable quality to any other; what it may be in practice I hope to hear in the discussion.

Of double tricycles, the Sociable has been tried by many, and is practically a failure in so far as traveling quickly and easily is concerned. The Tandem, though it presents so objectionable an appearance, seems likely to become a favorite, for it surpasses any single tricycle, and rivals the bicycle in speed. How it may compare in comfort or in safety with the single machine, perhaps those few who are well acquainted with them will say; at any rate, in the case of the Humber, greater stability is given to the steering owing to the weight of the front rider.

Time will not allow me to say more of these machines, or to attack the subject of steam, electric, or magic tricycles, which I had hoped to do. With steam and electricity we are well acquainted; by magic tricycles, I mean those driven by a motor which, without any expense, will drive one twenty miles an hour, up or down hill, with perfect safety. Highway regulations, and certain reasons not well understood, have at present prevented these contrivances from making a revolution.

There remains one machine which must be considered separately, for it cannot be classed with any other. This is the Otto bicycle. My opinion of this machine is so pronounced that I do not care to state it fully. I shall merely give the reasons why I prefer it to anything else, and in so doing I shall be taking the first step in the discussion, in which it will be interesting to hear from riders of other machines the reasons for their preference.

In the first place, the evils of a third or little wheel, the cause of trouble in all tricycles, are avoided. There is none of the vibration which makes all other machines almost unbearable to Ottoists, vibration which tricyclists have learned to consider a necessary accompaniment of cycling, but which has, no doubt, been diminished by the use of the spring support of the front-steering Humber. It would be presumptuous in me to make any remarks on the effect of this vibration on the human system; we shall all be anxious to hear what our Chairman

has to say on this point. By having only two wheels we have only two tracks, so that we can travel at a fair speed along those places in the country called roads, which consist of alternate lines of ruts and stones, where a three-track machine could not be driven, and where, from the quantity of loose limestone in the ruts, a little wheel of a two-track tricycle would be likely to suffer. By having no little wheel, we can ride in dirty weather without having the rest of our machine pelted with mud, so that cleaning takes less time than it does with anything else. As I have already remarked, the small wheel is the culprit which makes the bicycle and tricycle drive so heavily on a soft road. The ease with which the Otto can therefore be run through the mud, astonishes everyone. Having no little wheel, we can obtain the full advantage of the high 56 inch wheel, which almost everyone prefers. As I have ridden all combinations, from a 50-inch geared up to 60-inch, to a 60-inch geared level, I can speak from experience of the increased comfort to be derived from these large wheels, though for speed only they do not compare with the smaller and lighter wheels geared up. A further point gained by the use of two wheels only is the fact that the whole weight of machine and rider is on the driving-wheel, as it is also on the steering-wheels, so that by no possibility can the wheels be made to slip in the driving, or to fail in steering from want of pressure upon them.

The most important consequence, however, is the absence of any fixed frame. In all machines, bicycles and tricycles, with the usual fixed frame, a position is found for the saddle, which is, on the whole, most suitable. For some particular gradient it will be perfect, on a steeper gradient the treadles will be further in advance, but with a steeper gradient the rider should be more over the front of the treadles. To get his weight further to the front, he has to double up in the middle, and assume a position in which he cannot possibly work to advantage. The swinging frame of the Otto carries the treadles, of necessity, further back, so that the Ottoist when working at his hardest, is still upright, with his hands in the line between his shoulders, and his feet and his arms straight, so that he can hold himself down, and employ his strength in a perfectly natural position. On going down a slope, the fixed frame of a bicycle or tricycle leans forward, and places the rider in such a position that extra weight is thrown on his arms and shoulders, whereas the swing frame of the Otto goes back, and the rider of necessity assumes that position in which his arms are relieved of all strain. In so far as the general position taken by the automatic Otto frame is concerned, nearly the same effect can be obtained by using the swing frame of the Devon tricycle, which can be shifted and locked in any position which the rider wishes, or by the sliding saddle which can be slid backwards or forwards and locked so as to place the rider in one of three positions. Though the rider can by these devices assume nearly that position with respect to the treadles which is most advantageous, he cannot obtain that curious fore and aft oscillation made use of by the Ottoist in climbing hills, which, as the model on the table shows, enables him to get past the dead points without even moving, and which, therefore, makes the Otto by far the best hill-climbing machine there is, if account is taken of the high speeding with which all Ottoists ride. This is a proposition which none who knows the machine will question for one moment.

The freedom of motion resulting from the swing of the frame of the Otto gives a pleasurable sensation, which those who have only experienced the constrained motion of a three-wheeler cannot even understand.

The very peculiar method of driving and steering which seems so puzzling to the novice, especially if he is a good rider of other machines—for in that case he is far worse off than one who has never ridden anything—give the rider, when he is familiar with them, a control over the machine which is still surprising to me. In the first place, the machine will run along straight, backward, or forwards, so long as the handles are let alone. This automatic straight running is a luxury, for till a deviation has to be made, the steering handles need not be touched, and the rider may, if sufficiently confident, travel with his arms folded or his hands in his pockets. The rigid connection between the cranks and the wheels does away with all the back-lash, which is so unpleasant

with chain or toothed-wheel gearing. There is no differential gear or clutch, but the machine possesses the advantage of the clutch over the differential gear when meeting with unequal resistance on a straight course, for each wheel must travel at the same speed; but, in turning a corner, instead of driving the inner wheel only, which is done by the clutch or both wheels equally, which is the case with differential gear, each wheel is driven, but the outer one more than the inner. At high speeds, the steering of the Otto has this advantage, that whereas, with a given action on a tricycle, the same deviation will be effected in the same *space* at high as at low speeds, the same action on the Otto will, at high speeds, produce the same deviation in the same *time* as it does at low speeds; and so instead of becoming more sensitive at high speeds, as is the case with the tricycle, the steering of the Otto remains the same. This is because the steering of the tricycle depends on a kinematical, that of the Otto on a dynamatical principle.

In another respect, no machine can approach the Otto; at almost any speed the rider can, if there is reason, instantly dismount, by which action he puts on the brakes, and the machine will save him from falling, stopping with him almost instantly. As is well known, we can move backwards and forwards, we can twist round and round in our own width, or can ride over bricks with impunity.

One objection to the machine is the difficulty of learning, which is considerable, but which presents no danger. This difficulty has been much exaggerated, for before the present powerful brake was applied, it did require considerable skill to ride it down a steep hill. The way to do this must still be learnt, but it is now comparatively easy. For going down steep hills, the front-steering tricycle is without a rival; I do not know what other machine will do this better than the Otto. Lastly, the foot straps, which would be a great advantage on any machine, if only they were safe, are not—though none but riders will believe it—in any way a source of danger on the Otto. Having ridden this machine for close upon 10,000 miles, I can speak with more authority on this point than can those who are not able to sit upon it for a moment.

The only disadvantage which the machine presents is the fact that it is impossible to remove the feet from the pedals while running without dismounting; but though they must at all times follow the pedals, the Ottoist is not, as is generally thought, working when descending a hill.

The enthusiastic terms in which every one who has mastered the peculiarities of the Otto speaks of it would be considered as evidence in its favor, if we were not all considered by other cyclists to be in various stages of lunacy.

THE SEWERAGE AND REFUSE-DISPOSAL OF TOWNS.

By Prof. VIRCHOW.

From Abstracts of the Institution of Civil Engineers.

At the tenth meeting of the German Health Society, the following six theses were submitted by Professor Virchow, of Berlin, with a view to their discussion, but not for formal adoption.

1. Water-cleansing and water-seals are essentially needed for soil-pipes in houses.

2. Long-continued storage of fecal matters, either in middens or cesspools, in boxes or in tubs, must be avoided.

3. Choice may be made, in accordance with local circumstances, either of the direct removal of the excreta from dwellings in tubs, or of their discharge into closed channels or drains.

4. The introduction of sewage into public watercourses is in all cases objectionable. In towns having upwards of 100,000 inhabitants, this practice should in no case be permitted. In towns under 100,000 it should only take place where the conditions of current-velocity are especially favorable, and then only when proper precautions are adopted for disinfection and defecation.

5. The introduction, also, into public

watercourses of street and house drainage water, in the case of large and moderate sized towns, should only be permitted after thorough deposition of the sediment, which process may require to be further aided by chemical treatment, in accordance with the quantity and quality of the water which has to be dealt with.

6. The agricultural employment of fecal matters must be subject to strict sanitary supervision; but no more should be expected from sewage grounds, in the vicinity of towns than what has been insisted upon in the case of ordinary agricultural operations of a like nature.

In dealing with the first proposition, Professor Virchow stated that even Captain Liernur, who had been foremost in asserting the sufficiency in his closets of a seal consisting of urine, had recently abandoned this position, and had admitted the advisability of the use of water. With respect to the second proposition, he pointed out the impossibility of ensuring the necessary sanitary conditions when any system, hitherto introduced, of storing excrement in the vicinity of dwellings was resorted to. Even in the case of tubs the intervals of removal were frequently so lengthy that dangerous decomposition might arise.

The three following theses are intimately connected, and Dr. Virchow alluded to the difficulty of removing polluting ingredients from water, and stated that he was greatly opposed to the discharge of fecal matters into streams. The self-cleansing powers of rivers, upon which so much reliance has been placed, have, he believes, been much exaggerated. Experiments at the Berlin sewage-farm have proved how rapidly a certain degree of improvement in polluted water may be attained, but they have also demonstrated how long and how far the evil effects of river-pollution may continue. He observed a growing tendency on the part of towns to resist the cost involved in dealing with polluted water; but, to prove its necessity, he stated that towns situated on the sea coast, where the speedy discharge of sewage into the sea would be considered the most ready way out of the difficulty of dealing with this question, were gradually calling for some better plan of disposing of their sewage. He noticed the difficulty of persuading agriculturists of the value of sewage water, and insisted on the need of providing sewage-grounds independent of the surrounding farmers, who will only take the sewage-water when it suits their purpose, and who frequently reject it when the town is most desirous of sending it to them.

With respect to his final proposition, he showed that often enough no difficulty is made when farmers apply excrementitious matters to their land, and which, when washed into streams and rivers by heavy rainfall, may give rise to wholesale pollution, whilst the least discharge of sewage into streams by towns is made the occasion of widespread complaint.

THE ELECTROMOTIVE FORCE OF ACCUMULATORS.—M. Reynier, the well-known electrician, has made experiments on three systems of secondary battery: (1) the Planté accumulator of reduced lead, peroxide of lead, and sulphuric acidulated water; (2) the copper accumulator of lead, copper, lead peroxide, acidulated solution of sulphate of copper; (3) the amalgamated zinc accumulator of zinced lead, lead peroxide, acidulated solution. His object was to test the electromotive forces of the combinations and find there variations of sulphate of zinc. The accumulators were not completely formed. The electromotive forces were measured during charge and discharge by the method of equal deflection. His results confirm those formerly obtained by M. Gaston Planté, and are as follows: (1) In the three systems of accumulators studied, the secondary electromotive force is notably more elevated during charge than during discharge. The ratio of the smallest of these values to the greatest may be called the *coefficient of fall.* It is a factor of loss which effects the efficiency of accumulators. (2) The fugitive super-elevation of the electromotive force augments with the intensity of the charging current and the electromotive of the source. (3) In the Planté accumulator the electromotive force is at least 1.95 volts during the charging and at most 1.85 volts during the discharge. The coefficient of fall is therefore 0.95 under the most favorable conditions. (4) In the copper accumulator the electromotive force is at least 1.43 volts during charging and at most 1.25 volts during discharge. The coefficient of fall is therefore 0.87 under the most favorable conditions. The copper accumulator is that which loses most. (5) In the amalgamated zinc accumulator the electromotive force is at least 2.4 volts during charging and at most 2.36 volts during discharge. The coefficient of fall is 0.983 in the most favorable conditions. The amalgamated zinc accumulator is that which loses least. (6) In practice the losses due to variations of electromotive force will be greater than are indicated above, because the times of charging and discharging are generally more rapid than correspond to these experiments.

THE SYSTEMATIC DIVISION OF LAND—A PRELIMINARY STUDY.

By HOSEA PAUL.

From the Journal of the Association of Engineering Societies.

When new territory, especially if of considerable extent, is put into the market, a systematic division is not only possible and practicable, but its advantages are so manifest that in modern times something of the sort is universally attempted with varying degrees of success. It is not difficult to hit upon some system that will be better than the haphazard selection that would proceed in the absence of any plan. It is so easy to accomplish this much that the subject is rarely a matter of thoughtful consideration or intelligent action, what is done being either in haste or left to incompetent hands, which circumstance may perhaps serve as an explanation why there are so few examples in laying out land, either in country or city, where the full capabilities of systematic division are fully brought out.

Systematic division might be defined to be the laying out of land into simple, regular geometrical figures, preferably rectangles of nearly uniform extent, and described by numbers recurring in regular order. It deals not only with the present, but to secure the best results it must in a measure forecast the future and provide for its needs; it must regulate yet not cramp the free play of individual action, by giving grooves and channels to lessen friction.

Among the advantages to be derived from systematic division might be enumerated:

1. By its providing for present requirements parcels of suitable size ready and convenient for examination and occupancy, without the delays caused by special selection, the consequent bargaining, and the necessity of special surveys.

2. By its recognizing the possibility of and providing for its future division into still smaller parcels.

3. Inasmuch as any regular figure will include land of varying worth, there will be a better opportunity of disposing of those portions of little value separately in connection with other parts which are more desirable. For instance, a rocky hillside, unsalable separately, may prove a useful addition to a lowland farm for pasturage, the growth of timber, or because of springs of water. In this way the seller can avoid the accumulation of undesirable remnants.

4. A regular division will better accommodate the uses to which land may be put either for the growing of crops, or erecting buildings upon. It aims to provide for "the greatest good of the greatest number."

5. Few advantages of regular division are so obvious, so striking and important as the increased ease and greater possibilities in the way of graphic representation.

6. This graphic representation is possible at the beginning, often as fully as needed for many purposes without other surveys than those actually made in laying out the divisions.

7. The surveys may be mainly shown by maps covering a considerable number of the divisions and the necessary facts of direction and distance noted in the lines themselves. Such maps can be easily copied or published, and convey almost at a glance an amount of information that would otherwise occupy a large and usually widely scattered spaces in written records of deeds.

8. Simplicity of description. The number of the parcel being given, the length of lines, acres, etc., can be omitted as information shown by the map, and usually expressed in better terms than by words attempting to transcribe from it.

9. By means of the greater ease of graphic representation the burden of taxation can be more equitably adjusted; each owner's interest can be marked off, and in this way none need be overlooked or forgotten.

10. Greater simplicity, uniformity and

certainty in the work of the surveyor, the regular divisions being used as a means of correction, adjustment and verification.

Although something of a regular subdivision of land has been possible in the United States ever since its first occupation by Europeans, very little in this direction was attempted in early colonial history, probably because its advantages were not appreciated as in later times. The early settlers in New England in this respect did not advance much beyond English customs. Much of this country is rocky and broken, and that was first reclaimed from the wilderness that seem best adapted for the plow, and the fields were consequently often of irregular outline, and the fashion of the times was to build stone walls after the English practice, not only for their permanence, but as a good way of ridding the fields of unwelcome bowlders. An inspection of village plans will show great irregularities, and to one accustomed to regular lots and rectangular crossing of streets such plans are a curiosity. Not only are the lot lines twisted about to an unnecessary extent, but the sides of the streets or highways are not always parallel to each other, or for that matter to anything else, but each side winds about regardless of its fellow.

In the State of New York there were formerly large holdings of a semi-feudal nature in several counties in the central part of the State. The patroons, as the holders of these large estates were called, leased out their land, refusing to sell. In the course of time the tenantry became dissatisfied and the landlords not yielding to their demands, the famous anti-rent agitation of 1840-46 was inaugurated, and though there were some agrarian outrages, the movement, which in some countries might have amounted to an outbreak or insurrection against constituted authority, took a political form and became a complete success, effectually breaking up such an unrepublican system. It is believed that the division of this territory is quite irregular.

One of the earliest examples of division by number on a large scale is that afforded by the Holland Land Company's large tract, which embraced several million acres of land in Western New York and North-western Pennsylvania. The name is derived from the fact that among those who, at various times during the progress of the revolutionary war, loaned money to the Continental Congress, were certain bankers in the old and wealthy Dutch city of Amsterdam. After the close of the war, being without other resources of repayment, this large territory was granted to a company composed of Harm Jom Huidekoper, Wilhelm, Willink and others. The divisions were termed tracts and designated by number. They usually contain about four or five hundred acres, being about a mile in length, a common form being a mile east and west by fifty chains north and south. The dimensions and directions seem, however, to be often varied without other apparent causes than those arising from imperfect surveys. The shapes of the tracts were sometimes made long and narrow to secure a frontage on some river, as is often done in the early French grants so common in Canada, and sometimes recognized and perpetuated in our public land surveys.

A very common practice in the wild and mountainous parts of Pennsylvania is to divide the land into tracts containing about a thousand acres. In some places, however, the State lands do not appear to have had any division at all. To encourge sale and settlement a sort of pre-emption or homestead right was given to whoever would settle and improve them. In due time an official surveyor would be called up to mark out a tract of such shape as might strike the settler's fancy, the main object being to inclose as much good land as possible, and leave out what seemed to be sterile and worthless.

Very often these claims were voluntarily abandoned before being paid for, a not uncommon thing in pioneer experience, and subsequent settlers ran new lines more in accordance with their own notions, but when once established they had to be followed by others. As may be imagined there was and still remains some confusion and overlapping of lines, and many nooks and corners were left out until the land became more valuable. Though these surveys were recorded, complete maps of such territory are very unusual, and some of the land is untaxed. The unit of measurement used is

the perch, divided into tenths, and for every acre sold six per cent. is added or "thrown in," for instance, an hundred and six acres is described as one hundred acres, "together with the usual allowance of six per cent. for roads," etc. Without this allowance it is called strict measure.

The Western Reserve of Ohio is a district which is comprised of the counties of Ashtabula, Trumbull, Mahoning, Lake, Geauga, Portage, Cuyahoga, Summit, Lorain, Medina, Erie and Huron, with a part of Ashland. About the beginning of this century this territory passed into the hands of the Connecticut Land Company, which was organized in 1795, with a capital of $1,200,000, there being 4,000 shares of $3,000 each. The purposes of the organization were merely temporary, inasmuch as instead of selling out the land, and dividing the proceeds, a partition of the same was at once instituted and carried into effect. Townships five miles square were laid out and numbered as ranges and towns, the ranges westward from the Pennsylvania line and the towns northward from the forty-first parallel of latitude, a system similar to that just previously introduced in the survey of the public lands adjoining. The township might be called the unit of the land company's division, the theory being that the townships were of equal value, inasmuch if by reason of an undue proportion of swampy or waste ground any one of them was deemed less valuable than the others, the adjustment was made, not by changing the price, but land in another township was added to it to bring it up to the average, the process being called equalizing, and those townships which were cut up into strips or parcels for such a purpose were called equalizing townships. The townships in this way having been brought to an average value, they were drawn by lot by the shareholders; and when this was done, the main object of the company was accomplished. The only surveys made by the company, therefore, were such as were required for this purpose, dividing the townships only where necessary for equalizing, and in such further division as was necessary to put the land into market, each proprietor acted as he saw fit. Generally speaking, without noting exceptions, if a township had a single proprietor it was divided into lots of from one to two hundred acres each. If there were several proprietors, the interest of each were called tracts, being designated by number, location as to north, south, east, or west, or taking a name from that of the owner, and their further divisions were known as lots. The survey of the townships by the Land Company was begun in 1797, and mainly finished in the course of four or five years. The division of the townships was begun immediately afterward, and very generally completed in the next ten years, or by 1815.

In some cases the owners of the tracts were in no haste to make sales, and consequently no division was made until a recent period. Other owners made sales from time to time without ever making a general survey or adopting a uniform plan.

In Summit county is the Portage Path, an ancient Indian trail about eight miles long connecting the waters of the Cuyahoga and the Tuscarawas. This trail passes near the city limits of Akron and crosses the water-shed between the St. Lawrence and Mississippi basins. At the beginning of this century it was a well-worn footpath through the forest, and as such it had been used by the Indians for a longer time than their traditions extended. It was so well-defined a highway that it was often a dividing line between tribes, and for a number of years was by treaty the line of white supremacy. Probably every vestige of the trail itself has now disappeared, but by surveys its location is fairly established and marked, a necessary circumstance, inasmuch as this ancient trail of the savage is the line of individual ownership to-day.

That part of the Reserve embracing 500,000 acres covering Huron, Erie and parts of Ashland and Lorain counties, which is known as the Fire Lands, was granted to the inhabitants of New London and other towns in Connecticut, who had sustained losses mainly by fire from the incursions of British troops during the revolutionary war. The loss of each individual having been determined, their interests were placed in the hands of trustees who, following the example of the Connecticut Land Co. in the other part of the reserve, made an actual partition of the land and distributed it by

lot, the partition, however, affording much smaller parcels. The first division was to cut the township into four quarters called sections, and numbered thus—

3	2
4	1

Each section would therefore contain about four thousand acres.

These were again subdivided into tracts and lots, and although no great uniformity was observed it had the advantage of being done by one authority and at one time, and what is of scarcely less consequence, very fair maps were made and the field notes, etc., generally preserved, and are now extant in a good state of preservation at the recorder's office of Huron County, the original limits of which formerly comprised the whole of the territory in question.

In this respect at least the trustees discharged their duties more faithfully than did the Connecticut Land Co., who were very remiss about getting up maps, having field notes kept, much less to preserve them; and as for the private survey of townships, the taking of field notes and the compilation of maps was something that rarely received proper consideration, and sometimes none of any consequence were ever prepared, others have been lost and others are comparatively inaccessible to the public, being in the hands of private persons, who consider them little better than old rubbish that they are gradually getting rid of. The only systematic attempt to collect these maps and papers is that made by the Western Reserve Historical Society.

The execution of these early surveys was often very imperfect. The instruments used consisted of a two-rod iron chain and a small compass with a needle four or five inches long. Though the surveying party usually consisted of but four men, besides cooks, packmen, etc., the lines were run with great rapidity, sometimes ten or twelve miles a day. The surveyor would plant his Jacob staff in the ground, place the compass upon it, level it with the needle (the only means afforded), then setting it in the desired direction, instead of sighting to a pole or staff held by an assistant, would pick out such tree or other object ahead that was on or near the line of sight. A glance was usually sufficient, and then the surveyor would set out to the point observed to repeat the process, while the chainmen and the marker would follow after, the latter blazing such trees as were within his reach. Though the country was thickly wooded, it was often comparatively free from undergrowth. It was often possible to see to a considerable distance, so that with a little care the lines could be made straight for some distance; and, the ground often being nearly level, could be measured with considerable accuracy. Such results were, however, rarely attained, and in many instances the imperfections are so great as to be best accounted for by the old traditions, that the whiskey carried to prevent the bad effects of the bites of the then numerous rattlesnakes sometimes got into the heads of the whole party without improving the character of the work.

It is doubtful, taking into consideration the better general surface of the country, whether the actual work of the surveyor on the Western Reserve of Ohio was as well done as on the Holland Tract, and it is believed the records are not as perfect; but there was one great advance made, and that was in laying out regular numbered townships. Both were faulty from the absence of any well-defined plan of numbering tracts, and still more so in the neglect of the consideration of future subdivision.

One feature of the partition of the Rererve seems to be especially novel, and that was the ingenious method of equalization heretofore described, by which the units of division that had been determined upon were kept uniform. This principle could be adopted with advantage in a great variety of circumstances where land is partitioned off in severalty among those who have hitherto owned it in common. In attempting to adjust the different interests to the varying value of the land, regularity and symmetry of form are usually lost sight of, and thus a permanent disfigurement of outline may result from a merely temporary cause, that might be easily avoided if, instead, a regular division is made, with uniform units, making the divisions of average value by add-

ing fractional parts from divisions reserved for such a purpose.

Connecticut, though perhaps the most persistent and unfair of them, was not the only claimant of the northwest territory. Virginia asserted her right to a portion of it, and there was, in consequence, granted to that State certain lands in Ohio lying between the Scioto and Miami rivers. It was set apart for the benefit of revolutionary soldiers, hence the name of Virginia Military District. No systematic survey of the territory was made, but the early settlers picked out the land wherever they could find any that was vacant, and of such shape as suited them best, those coming later being more and more retricted as the process of selection proceeded. Everywhere there is great variation in the area of adjoining tracts, and in hilly districts and along the rivers, especially, very irregular boundaries. The tracts are numbered, not, however, in their geographical order, but merely as to their time of location, perhaps the only way possible under the circumstances, but rendering the numbering of little practical use.

THE PUBLIC LANDS.

The plan pursued in laying out the public lands need not be described here further than it provides for townships six miles square, and sections one mile square. Considering the lack of precedents the plan is deserving of the very highest praise.

There is one drawback which many must have felt if they have never complained of it, and that is the awkward way of numbering the sections. A more confusing arrangement could not have been easily found, and many persons after long practice are unable to mentally locate them in their relative order. While the ancient Hebrews wrote from right to left, and the Chinese arrange their characters in vertical columns, such is not the most convenient way for people accustomed to other methods, and it would have been vastly simpler and more easily remembered if, in numbering sections, they had been arranged as ordinary writing is—something as shown in the plan in the margin.

In this plan, which might be termed a natural or obvious one, the numbers increase downward by regular addition of six. This matter of numbering is here alluded to, not because a change is now recommended, or because the plan shown is a perfect one, but simply to call attention to the general subject of numbering —something not without its importance —as an instance where correct principles are entirely disregarded. The system is, however, uniform throughout a vast territory, and once learned, in connection with the more simple notation of the meridians, parallels, townships and ranges, locations are easily described, and as the sub-division of a section is well provided for, definite descriptions of small parcels of say ten acres can be given without reciting the length or direction of a single

1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

line. This has greatly simplified the work of the conveyancer, the abstracter, the assessor and tax gatherer, as well as that of the surveyor. For the ordinary operations of the surveyor the sectional system is admirable. The original field notes and maps are a matter of public record, and show very full details of the length of lines, the meandering of streams and a description of the corners and bearing trees. The corners of a section or quarter section once established the subdivisions are matters of bisection and distribution, and thus working from the whole to parts, bearing a numerical ratio to it, great accuracy is possible, in particular those due to imperfect standards of measure can be almost entirely eliminated.

In an open or level country all of the corners along a section boundary can generally be put into a single line, thus fixing the position of a line by points

beyond it in its own direction, and not depending on cross measurements or rectangular co-ordinates. In wooded or hilly districts the half-mile points can be used instead, and the intermediate points put in the same way without any unreasonable expenditure of time in running long lines.

The improvement that might be made in the general plan of laying out the public lands will not now be discussed. The more noticeable faults are not so much of deficiency of plan as those caused by defective execution of the surveys. Being done on the frontiers of civilization, the work is at best done at a disadvantage, and often with considerable hardship, if not actual peril to those engaged in it. There is little inspection by competent officials, and still less criticism through the effective process of public opinion. As there is competition the work must be done cheaply, and of necessity rapidly. Patient, thorough work takes time and money—sometimes so much that an accurate survey would cost more than the land was worth.

These contract surveys are, however, often erroneous beyond all excuse, and the marking of corners little more permanent than the surveyor's own footprints; and, worse still, though full sets of field notes were returned, they were made up from imagination, no survey having been made at all. It is generally possible, however, to make resurveys, and thus obviate some of the inconvenience arising from this source.

That there should be great precision is not often possible under the circumstances under which the most of such surveys are made is no doubt true, and the absence of it is not of itself so serious a matter as many are apt to believe. Indeed, the thing of most importance besides the prevention of unnecessary and easily prevented errors, is the conspicuous and permanent marking of corners. This well attended to, minor inaccuracies of measurement and area may be overlooked as a matter of less importance, and which can be attended to and improved upon as increased values justify more accurate surveys.

That the plan of laying out the public lands is perfect would not be claimed. Doubtless something of value could be learned from the experience of Canada and other countries which have had occasion to solve the same problem. In Canada the principal of decimal division is recognized, but a description of the system is omitted from lack of time to fairly present it in these limits.

But the sectional system is so far in advance of any examples previously afforded in any of the older States, it might be termed, in comparison, perfection itself. Nor is it believed on an average that its execution is worse. It is interesting to observe after the lapse of thirty, forty or fifty years, or even longer, since the settlement of particular districts how closely the lines of ownership follow the section lines.

Among the earliest of these sectional surveys are found in Columbiana, Carroll, Stark and other counties in Ohio. Though over eighty years have passed, and several generations have occupied the soil of these important and thriving civil communities, the sectional divisions are by no means supernumerary or obsolete, the most noticeable variations being found in the hilly districts, where the roads are necessarily winding, and in some instances the deep ravines have been used instead.

In the more level districts the variations are exceptional, and in many counties in States farther west such variations are almost unknown.

The credit of designing the public land system has been usually awarded to Col. Jared Mansfield, Surveyor General of the United States. The great Jefferson, it is said, also honored the subject with his attention, and doubtless each of these and others did something toward perfecting and shaping the plan adopted, but Col. Charles Whittlesey, an authority of the very highest respect, in his valuable paper on "Ohio Surveys," recently published,* is inclined to award the palm to Thomas Hutchins, as the man in whose brain the conception first found lodgment, and who was one of the instruments in having it adopted. The honor is a great one, and his name may be fitly listed on the roll of great benefactors of mankind.

Hutchins was a captain in the Sixtieth Royal Regiment, and engineer to the expedition under Col. Henry Bouquet, in 1764, during which time, in the lonely

* Transactions Wes. Res. & N. O. Historical Society. Tract No. 59.

forests of Ohio, remote from the scenes of civilized life, and from contact with men or their accumulated experience, as recorded in books, he evolved in his mind the outline of the plan which was afterward adopted with but little change during the time he was geographer to the confederation, an officer similar to the surveyer-general, afterward filled by Mansfield. Hutchins died in Pittsburgh in 1788, and his remains lie unnoticed in the cemetery of the First Presbyterian Church of that city. History has certainly done him scanty justice, and it is worth while to have said a few words to do something toward rescuing his name from oblivion.*

The principle of rectangular division was adopted at a very early period in laying out American cities, the most noticeable exception being in Boston. New York, Philadelphia and Chicago are laid out with great regularity, and even in Boston the newer parts are laid out in the same fashion. In the western cities the public land system affords an excellent basis. In Chicago, for instance, many of the well-known thoroughfares, such as Madison, Twelfth, Twenty-second, State and Halsted streets, and Ashland and Western avenues, are upon section lines, and many of the other streets are upon regular fractional divisions of them.

The rectangular system has been criticized mainly from its lack of convenience when it is desired to take a diagonal course, and on account of its supposed offence to an artistic or an æsthetic taste. To meet this latter objection some towns, mostly suburban, have been laid out, an instance in point being Riverside, near Chicago, where the lines of the streets are made up of curves something in the manner of the walks or drives in a park or cemetery. However well such an arrangement might suit for residence with ample grounds, it might be quite another thing for small lots and business centers. It would at least require greatly increased care in making the surveys, or the restoration of lost lines be very difficult and uncertain.

Some writers urge that the web of the spider offers us a most admirable plan, and the national capital has been laid out with some reference to this theory, another instance being the little city of Watertown, New York. In Cleveland there is also something of the same sort, though fan-shape would perhaps better describe the flare or gradual divergence from parallelism exhibited by Superior, Euclid, Garden and Woodland streets and avenues. If it were a fact that everyone must daily or constantly go to a certain point—say, for instance, to the post office—no arrangement could be better, and anything else would be so exasperating as to force the opening of new avenues to bring it about.

Such is rarely, however, the case. The business and manufacturing interests of a modern city are often widely scattered, and rarely tend to a common focus so definite as to require any such arrangement. There are east sides and west sides, north ends and south ends, uptown and downtown, water fronts and railroad fronts—each with its own interests and attracting its special following.

The advantages of representing upon paper the ownership of land are so varied and serve so many public ends, that in a progressive community it is regarded as something indispensable. One of the first attempts of this kind was when, nearly nine hundred years ago, in the reign of William the Conquerer, the celebrated Doomsday Book was prepared. Officers were appointed to traverse the kingdom and make out a list of the landowners (loyalty to the sovereign being, of course, a condition of ownership) and their possessions, something after the manner of the modern assessor. The book is still extant, and has always been regarded as an authority almost as conclusive as inspiration, the object for which it was prepared being to inform the monarch of the resources of his kingdom, and on whom he might call for support.

It is something over one hundred years ago since the British ordnance survey was begun. Its original object was to make a map of the kingdom for the

* Since the above was written there has appeared in a recent number of this *Journal*, Vol. 2, p. 282, an interesting and valuable article on "The Origin and Authorship of the Present System of Government Land Surveys," by H. C. Moore, of St Louis. Mr. Moore has looked up at the Marietta, O., University some of the original papers of Gen. Rufus Putnam relating to the Ohio Company's purchase, in which the plan is outlined as early as 1783. To fully settle the question is a matter requiring further research. Very possibly the result of such investigation would be that the honor is to some extent a divided one, inasmuch as the plan may have been developed, modified and changed by different persons.

use of the military authorities; but, as it progressed, its scope has been enlarged, until its aim is a complete and thorough representation of the topography of the kingdom. The fullness of its detail may be judged by the scale used, that for the whole country being $\frac{1}{2500}$, and for villages and towns $\frac{1}{500}$. It would seem possible, from such a map, to make a very close approximation of the proper route for a railroad or similar public work.

In this country the preparation and publication of maps, except of the sea coast, the great lakes, and some of the uninhabited territories and mineral districts has been mainly through private enterprise, which has rarely conducted surveys of any consequence; and, where there are no regular divisions, such maps are necessarily incomplete to an extent that something more thorough and extensive is now a well-recognized public need, and, with the constant reiteration of the demand, may be set down as very likely to be early undertaken. But, whether such a general survey is made or not, the existing divisions, especially the regular ones, should be kept up. They are the framework or skeleton to which all ownership clings, and the preservation of their corners and their restoration and marking when lost may well, and ought to, receive the attention of the State, and be no longer left to the caprice of individual interest.

Whatever may be accomplished in a general way by geodetic and trigonometric surveys, the importance and necessity of which need not be undervalued, however fully and satisfactorily they may solve various interesting and important scientific questions, as, for instance, the figure of the earth, as well as serving many practical ends in map-making and the accurate determination of levels, the representation of contours, and in so many other ways justify their existence to an extent that will make their cost seem insignificant in comparison to the results attained. It is, I think, a grave mistake too generally prevalent to suppose that the lines laid down by such surveys will ever be generally relied upon to establish the lines of individual ownership. In the nature of the case the lines of a trigonometrical survey are largely artificial ones, made for a particular occasion, and, however carefully selected and good originally, in the lapse of years may become wholly unsuitable by reason, for instance, of the erection of buildings or the growth of trees. The initial points, too, will often occur in fields, or at points where no one is specially interested in their preservation or to be informed of their whereabouts, or, if often resorted to, might cause complaint from the farmer who might find it convenient to have them removed. It must be borne in mind also that were such points used, and the angles turned from them, it would still be necessary then as now to actually run, measure and mark the property lines, for that indeed is the object for which nearly all land surveys are made. In actual practice the accurate determinations of and marking of lines of the various trigonometrical surveys has not often been carried down far enough to make them convenient for such use, much of the detail work having been done with the plane table. The restoration of lost boundaries, too, is often a question of evidence, much of which can only be found on the line itself. Such is the rule of law, the final arbiter, to which all must submit when controversy ensues.

NEW METHODS OF PRODUCING STEEL PLATES. —Dr. Henry Muirhead, President of the Physiological Society of Glasgow, has recently brought before that body some particulars of a method of manufacturing steel plates for shipbuilding and boilermaking purposes which is of much interest, although its leading feature is not a novel one. It is the invention of Mr. Joseph Whitley, of Leeds, who has erected works for prosecuting the manufacture. Briefly describing the process, Dr. Muirhead said, a hollow metal cylinder, lined with ganister or other brick, revolves at high speed, the axis being horizontal. A gutter or rhone perforated with holes passes into the interior, along its whole length. Into this gutter is poured molten mild steel, which, escaping through the holes, is carried round by the swiftly revolving case, and is formed into an inner cylinder of steel of an inch or more in thickness. This cylinder, while still hot, is drawn, cut across by means of a saw, put into a rolling mill, and rolled to the length and thickness required. Writing to Dr. Muirhead, Mr. Whitley said: "Required a plate for shipbuilding; then, given a mould 5 ft. in diameter and 5 ft. long, in it I cast a cylinder an inch thick. This when taken out and cut is fully 15 feet long and 5 ft. broad. It is then rolled down to half an inch in thickness. Such a plate is then 30 ft. long and 5 ft. broad. The present mould is 9 ft. long and 5 ft. in diameter. With it I successfully cast a mild steel shell weighing about 30 cwt."

YACHTS AND YACHT SAILING IN 1884.

From the "Nautical Magazine."

It is said that the season which has just commenced is likely to be a good one for yacht racing, that contests promise to be more than usually numerous and prizes more than ordinarily valuable. The old British cutter rig reigns supreme, schooners and yawls being scarcely heard of. It appears that the extreme types of the last few years are only giving way to something more extreme, and that the divergence between cruising craft and vessels built for purposes of racing is greater than ever. The turn-out of the present year is chiefly in the smallest and largest vessels; new three-tonners are pretty numerous, and there are three racing craft of the largest size which are likely to make 1884 a notable year in the competitions between large cutters. All of them are composite boats, and we may say that this system of construction, combining as it does great transverse strength with lightness of build, together with the advantage of coppered bottoms, is likely to keep its ground for pleasure craft, the expense of building, which is a bar to its use for merchant sailing ships, being of comparatively little consequence in the case of yachts, while its peculiar advantages in them are of greater value.

We may first mention the *Genesta*, built for Sir Richard Sutton, by Messrs. Henderson, of Partick-on-the-Clyde. Her length on the water line is 81 ft., registered length 85.6 ft., beam 14.6 ft., depth of hold 11.75 ft., greatest draft 13 ft., and register tonnage 74. She is described as having a very clean afterbody, but rather fuller forward than other recent yachts. Her racing tonnage is 80, and she carries 64 tons of lead ballast, of which 60 tons is in the lead keel. It was said that she would sail her first race in the Royal Thames match from the Nore to Dover on the 7th June, but she is at present in Cork, repairing damage sustained in her first sea cruise.

The *Marguerite*, of 60 racing tons, launched on the 12th ult., from Messrs. Inman's yard at Southampton, for Mr. Foster Connor, has a length of 74 ft., beam 13.5 ft., and draft 12.5 ft. She has a lead keel of 51 tons, and 6 tons of ballast inside. Her frames are steel, topside plank teak, and bottom pitch pine, and it is said she has a greater sail area than ever before carried over 13½ ft. beam.

The *Irex* is building by Mr. Fay, of Southampton, for Mr. John Jameson, but it would appear that she is hardly likely to be ready for the earlier races of the season. Her dimensions are—length on water-line 83 ft., registered length 88 ft., beam 15.1 ft., draught 14 ft., register tonnage 75. She will carry the heaviest lead keel ever cast, nearly 72 tons. She also has steel frames.

"These three vessels," says a recent writer in the *Times*, to whom we are indebted for some of the preceding figures, "will, with the *Eryana*, *Marjorie*, *Vandward*, and *Samœna*, make up a goodly fleet indeed of heavy weights. The *forties*, which showed such grand sport last season, are not likely to be in force, but new boats in the twenty, ten, five, three ton, and the length classes will invest the battles of those sporting sections with new life and interest. It is only reasonable to assume that a forward movement in regard to speed will be apparent in the three new vessels before referred to." Of the four vessels named as conspicuous in last year's racing, the first two will have more sail area than previously, and hence it will appear that both as regards new craft and improvements in old ones there is likely during the next few months to be keen competition for prizes.

One feature common to the three vessels, of which we have given the dimensions above, cannot fail to have escaped notice, the extraordinary amount of lead ballast and the great depth compared to beam now characteristic of the racing yacht. In smaller craft these features are even more strongly marked. Thus a new yacht at Plymouth is described by a correspondent to the *Field*, as follows:—"I judge her to be about 11½ tons displacement, strongly built, with the scantlings of a 10-tonner. She has a lump of lead of about 7½ tons on the keel. She is

over 30 feet on the water-line, with large overhang and flare abaft, and will draw 8 ft. How much farther is this 3-ton folly going?" Mr. Dixon Kemp, who has written so much and so ably upon the whole question, attempts in a recent number of the *Field* to answer the question thus put by reference to a design to which has been given the name *Ne plus ultra.* It is intended to show the longest and narrowest yacht possible under the present Yacht Racing Association rule which a crew could live in, unless, as her designer says, "a man succeeds in getting a thin crew accustomed to sleep on their sides, and who would not mind coming on deck to turn round." This *reductio ad absurdum* of modern yacht construction, described by Mr. Kemp as "the plank on edge," has a length on water line of 38.5 ft., beam 3 ft., and draft 11 ft., her load displacement being 19.8 tons, of which 15 tons is lead ballast on the keel. The tonnage by the Yacht Racing Association rule is, as we have indicated, 3 tons; in fact, a start is made with 3 ft. beam, and then to give 3 tons by the formula,

$$\frac{(\text{length} + \text{beam})^2 \times \text{beam}}{1{,}730}$$

the length necessary is 38.5 ft. By the Royal Thames rule, which is even still more applicable to present types, and of which the formula is

$$\frac{(\text{length} - \text{beam}) \times \text{beam} \times \frac{1}{2}\,\text{beam}}{94}$$

the tonnage is 1.7, while by the sail area rule, at present admitted as an alternative rule by the Association, the tonnage is 12. The formula for the sail area rule is

$$\frac{\text{length} \times \text{sail area}}{6{,}000}$$

In each of these rules the *length* is length on the water-line. From what we have said it will be thus evident that yachtsmen are as far off as ever from a system of measurement which will give an equitable basis for time allowance, and that the present methods are but a very small improvement upon the old one. The alteration of the time-honored rule of the Royal Thames Club, which was for long the standard everywhere, was rendered necessary by the appearance of the *Jullanar* a few years ago. In the old rule the length was taken from stem to sternpost, and the *Jullanar*, of which a detailed and interesting description is given in Mr. Kemp's "Yacht and Boat Sailing," has about 10 ft. of immersed counter abaft the post. To meet this new departure it was decided to measure length on the water-line. At the time that further changes in the yacht tonnage rules were under discussion, we suggested, not as a theoretically exact rule, but as a good practical solution of the difficulty, a system of measurement by which the product of the three important dimensions—length on the water-line, beam, and draught—should be multiplied by a factor, determined so as to give an average result not far from the present nominal tonnage of vessels of reasonable form and dimensions. This, we still think, would have been better than the rule which was adopted, and would have been at least more easily ascertained than the sail area tonnage, now so extensively advocated, although there can be no doubt of the fact that the sail area rule is a much better measure of size than anything else at present in force.

The ideal system of yacht measurement was recently described by Mr. R. H. Froude, an eminent authority on scientific questions connected with naval architecture, as one which should "handicap all tendencies to depart from an ideal form and fitting up of a yacht." These few words indicate the whole difficulty, as probably no two yachtsmen would agree as to what was an ideal yacht. It is in the nature of things, that whatever rule is adopted, there will still be racing yachts and cruising yachts, and that the vessel which excels in one respect will be at a disadvantage in the other. Still there can be no doubt of the faultiness of a rule which induces a designer to use up so large a portion of his displacement in carrying an immense lead keel, thus uselessly increasing the expense of the vessel, for no commensurate advantage. While remarking upon the prominent defects of the present type of racing yacht, it must, however, not be forgotten that they have usually a very large range of stability, and are, in fact, life-boats which it is impossible to capsize.

Mr. Froude suggests as a remedy for the existing state of things:—"(1.) That a committee of thorough yachtsmen should

decide, among existing forms of yachts, which are eminently their ideas of cruising yachts. (2.) That by obtaining practical tests on different days in various states of weather, purely empirical diagrams should be drawn up, showing to what extent additional length should be handicapped, to what extent iron construction against wood should be handicapped, to what extent difference of area of sail should be handicapped." He also suggests that "with regard to area of full sail, it seems to me that to obtain the sail-carrying power by heaving a yacht down to her sailing inclination, with a tackle attached to a spring balance, is a much more satisfactory method of working to the same object, as it leaves the yacht free to adapt her canvass to the weather and points of sailing during the race." What Mr. Froude thus proposes to measure is the inclining moment of sail area, corresponding to a standard angle of inclination. This depends upon the area and the height of the center of effort of the sail, and thus includes the element of height of sail twice, but a rule could be framed whose practical effect would be to eliminate the extra dimensions.

It is said that during the present season a number of clubs will try the accepted sail area rule of the formula we have given; the principal objection to it on the part of yachtsmen is that the vessel's tonnage is subject to alteration by change in her rig. The grounds upon which we advocated a rule based upon the three principal dimensions of the vessel were, that sail-power depends upon length and stability, while stability depends upon beam and lowness of the center of gravity, the latter in the case of ballasted vessels depending upon draught. A good racing tonnage rule is certainly a *desideratum*, and we should think the yachting community will not much longer be without one. No rule can, we think, permanently place comfortable pleasure craft on an equality with racers, but it would be easy to reduce the present wide disparity, and afford room for the development of other and more desirable things than heavy lead keels. There is the further objection to racing yachts of the present type, that the lead keel and its connections necessary, make the vessel very costly, while as things have gone of late years she is only successful till a designer produces a vessel with still more lead, and then the ex-racer is next to useless.

Mr. Dixon Kemp's "Manual of Yacht and Boat Sailing" takes rank as the standard work upon the subject, and must, since its first publication, have been of invaluable assistance to owners of pleasure craft, from the dimensions of the racing cutters we have been describing to the tiny sailing canoe. In the earlier editions there were sections treating of yacht-designing; they, however, have since been embodied in a separate work, and, in its later form, the Manual has been entirely devoted to those parts of the subject which are of interest to the practical yachtsman. No pains have been spared to make the work a complete guide to the selection, management, and racing of pleasure craft of all sizes and descriptions. There are, moreover, special chapters upon local types of boats and yachts, showing how special forms of vessels have arisen either from local exigencies or fashions.

Mr. Kemp begins by advice as to the selection of a yacht, and comes to the conclusion that for cruising craft the rig should be cutter up to 80 tons, yawl from 80 to 150, and schooner above that tonnage; for racing craft he favors the cutter, but recommends a moderate tonnage, and, in view of our previous remarks upon the subject, we should certainly endorse this recommendation. Valuable information is given as to examination of the vessel, and as to the value of classes in Lloyd's Yacht Register, and in regard to the equipment, there are tables of sizes and illustrations of the various items. One chapter is devoted to the special question of seamanship, and another to the special management required in yacht-racing. By the title of Mr. Kemp's book, *boat* as well as yacht-sailing is implied; and accordingly much information is given upon canoeing, this part of the work being entrusted to specialists. Mr. Baden Powell contributes the section on canoes of the *Nautilus* type—that is, craft fit to sail on comparatively rough water, having good sheer, and yet coming under the definition of a canoe which he tells us "is a vessel propelled with a paddle or with sail by a person or persons facing forward; she is a vessel capable of navigating shallow water as well as open rough water, and she is a vessel not too large or heavy for land portage by two men when her

ballast and stores have been removed." Details of the construction and designs are given of several canoes of the *Nautilus* type and also of the *Pearl* type, the latter being written by Mr. Fredwen the designer of the original *Pearl* sailing canoe. Designs are also given of Mersey sailing canoes, and of an American river canoe.

Among the local types of yachts illustrated, are those on Lake Windermere, remarkable for the long overhang counter and heavy lead keels, the yacht of the Norfolk Broads of an almost opposite type, yet both carrying a large spread of sail. The remarks upon the Itchen boats are of additional interest from the fact that the standard of value for competitive sailing among them has been length only. Other notable local craft of which descriptions and designs are given are the Clyde yachts, Penzance luggers, and a large number of center board boats of various types and sizes. There is a chapter on ice yachting, in which the singular phenomenon of a vessel sailing faster than the wind is elucidated, and an appendix contains a dictionary of useful information on yachting. We believe that another edition of this valuable work is announced for the present season.

ON THE GASES SEPARATED IN STEEL CASTINGS.

By F. C. G. MULLER.

Translated for Abstracts of Institution of Civil Engineers.

The author in this paper replies to the criticisms on his former work contained in Mr. Pourcel's paper, read at the Vienna meeting of the Iron and Steel Institute, and to the remarks of Mr. Windsor Richards upon it. After pointing out that the cavities in unsound ingots are not the result of the enclosure of gas-bubbles in a liquid, but tubes resembling those of worms produced by the separation of gas from previously solidified metal, having their longer dimensions perpendicular to the cooling surface, he states that two theories of their origin have been proposed. The first of these, called the absorption theory, supposes that the fluid metal takes up gases from the air or the fire, which are given out again on solidification and cooling. Such an action is known to take place with silver and copper, and an analogous action is seen in the freezing of water, where the dissolved air separates and forms cavities very similar in appearance and radial arrangement to those of an unsound steel ingot. It is not necessary to suppose that the whole of the gas so taken up is separated, a portion being retained at a temperature far below that of solidification. In this respect the first separation of gas represents the first crystallization of mixed salts from a solution, and the residuum, the salts retained by the mother liquor.

The second theory, characterized by the author as the reaction theory, supposes the separated gases not to be previously contained but to be formed at the moment of separation by the reaction of dissolved oxide of iron upon carbon. This requires the gas in the pores to be of a definite composition, namely, carbonic oxide, while in the absorption theory no particular composition is specified. The part may be played by carbonic oxide, as well as by any other simple or compound gas.

The second theory is considered by the author as opposed to many observed facts. For instance, completely decarburized and overblown metal, when cast without any additions, gives off more gases in setting than any other kind, their volume being many times that of the metal, which cannot be due to reaction, as there is no carbon present.

Mr. Pourcel's explanation of the effect of silicon in producing sound castings, by its reducing action on dissolved oxide of iron, producing silica instead of carbonic oxide, is contrasted with the circumstance that German Bessemer steel is rich in silicon, and yet unsound ingots are common. Part of the author's experiments were made with steel containing 0.3 to 0.6 per cent. silicon and 0.8 per cent. manganese, and in the direct Besse-

mer process, steel with 1 per cent. of silicon is often produced, which rises so quickly that there is often scarcely time to stopper the moulds. Another fact is that in recarburizing highly silicized steel with spiegeleisen, a violent evolution of carbonic oxide takes place, showing that the reaction of carbon upon oxide of iron is effective even when the bath contains a notable quantity of silicon. In some cases the author has found an actual increase of silicon after the addition of spiegel or ferro-manganese, showing that only the carbon and manganese of these compounds were effective as deoxidizing agents. Again, in the ordinary German Bessemer process there is no sensible oxidation of silicon so long as carbon is present, its behavior being, in fact, similar to that of phosphorous in the basic process.

Although, therefore, there is no ground for supposing that the mere presence of silicon in the metal hinders the formation of gas pores, it is otherwise when an addition of a silicon compound is made before casting. This the author considers to be a proof of the accuracy of the absorption theory, as showing the phenomenon to be merely physical in its nature. Silicon increases the solvent power of steel for gases, so that the bath, when previously saturated, becomes only partially so by the addition, and therefore separation is prevented. Of course, if the opportunity is given, it may become saturated a second time, and its solvent power may be increased by a second addition of silicon, and so on. The latter statement is only put forward as a possibility, as there is no experimental evidence to show whether the solubility for gases is proportional to the content of silicon. It is more likely that an additon of 0.1 per cent. to a bath containing none may be more effective than an increase of an original 0.5 to 0.6 per cent. The first case is that of the Martin process, where highly silicized compounds are most effective. This simple explanation, the author points out, has not only been previously published by himself, but was given by Mr. Gautier a year since, at the meeting of the Iron and Steel Institute.

That small additions of foreign elements materially influence the solubility of gases in metals is proved by the analogies of copper and nickel. These metals, which, when chemically pure, give porous ingots from the separation of carbonic oxide and hydrogen; cast perfectly sound when an addition of 0.1 per cent. of lead is made to the first, and of 0.12 per cent. magnesium to the second when melted. It seems, therefore, extremely probable that silicon may have a specific action upon iron of a similar character.

The author then reviews the various analyses of gases given off by steel, commencing with those of Troost and Hautefeuille, in 1873, Parry's in 1874,* Regnard's in 1877, and his own in 1878-79. These are repeated at length, on the ground of their having been imperfectly reproduced in foreign journals.† The general result of the whole of these is to show that the gases liberated, whether by heating the metal in vacuo or boring it, consist essentially of 85 per cent. hydrogen and 15 per cent. of nitrogen. Mr. Stead's experiments, made for Mr. Windsor Richards in 1880, give an essentially similar composition. The supposition of the latter observer, that the hydrogen may be due to the decomposition of water by the friction of the metal against the borer, is shown to be untenable, as the shavings taken off when steel was slowly bored in air showed no tendency to tarnish, and if, therefore, there was no disposition to take up free oxygen, it is not likely that they would decompose water in a specially cooled apparatus in order to become oxidised. Even such a tendency, if it existed, would be checked by the reducing atmosphere produced when the first few centimeters of hydrogen had collected in the bore-hole. The enormous volume of gas, removed in Stead's experiment with the blunted borer, amounting to about eleven times that of the metal, shows that the whole of the intermolecular gas has been removed, owing to the metal being practically pulverized. This, however, is in accordance with the fact previously pointed out by the author, that the amount of gas removed depends upon the thickness of the shaving. That the volume of these intermolecular gases should be so large is, however, a new and important discovery. Parry, by heating in vacuo, obtained only a three to fourfold volume. The author considers that

* This should be 1872.

† The account is the same as that given in the Min. Proc. Inst. C. E., vol. lx., p. 499.

these gases are actually alloyed in the steel; that nitrogen is actually so contained is proved by the admirable experiments of Allen, and he is now at work upon a method for the quantitative determination of hydrogen. Both elements are integral constituents of the steel, and possibly may exercise an important influence upon its physical proportions.

Carbonic oxide is also contained in the intermolecular gases, but as it is only given off at a red heat, and not in the boring experiments, it is evident that it forms a more stable combination with the metal than either hydrogen or nitrogen.

In conclusion, the author points out that the results of some fifty experiments, made by different observers in different ways, show that hydrogen is the principal gaseous constituent obtainable from steel, whether in the gases from the molten metal, the contents of the cavities in the ingots, or the intermolecular gases of the compact metal. Nitrogen is a never-failing associate, while carbonic oxide is invariably subordinate in importance to hydrogen, and is never found in the larger cavites. It is most probable these gases are due to the decomposition of steam in the air or gases of the furnace, and that their effect can be neutralized either by the addition of silicon, so as to increase the solvent capacity of the metal, or that they can be separated mechanically by the rapid evolution of another gas on the addition of spiegeleisen.

REPORTS OF ENGINEERING SOCIETIES.

Engineers' Club of Philadelphia.—A special business meeting was held in Philadelphia, June 21, President Wm. Ludlow in the chair.

Prof. L. M. Haupt, Chairman of Committee on Resolutions with regard to the proposed change in the United States Coast and Geodetic Survey, reported the following, which were unanimously adopted and the Committee discharged:

"*Whereas,* We, the Engineers' Club of Philadelphia, have learned that a bill has been drafted in the sub-committee on Sundry Civil Appropriations of the United States House of Representatives, the purport of which is to merge the United States Coast and Geodetic Survey into the Navy and Interior Departments;

"*And Whereas,* Under existing laws and regulations, such a practical dissolution of this distinguished and efficient organization must result in a lowering of the high standard attained, without producing any equivalent on the score of economy or expediency;

"*And Whereas,* The changes now proposed were tested, both in 1834 and 1851, and in each instance proved a failure; therefore it is

"*Resolved,* That in the opinion of the members of this organization the proposed change in the status of the United States Coast and Geodetic Survey would be prejudicial to the best interests of the government service.

"*Resolved,* That the members of Congress representing the state of Pennsylvania be, and are hereby, respectfully and earnestly requested to oppose the passage of this bill."

The Secretary having arranged therefor, copies of the above were forwarded immediately after the meeting.

The Secretary reported upon the relations of the Club to the Custom House and Post Office, but delays his final report, as certain matters in relation thereto are still subject to controversy. Documentary and other evidence is on file, however, to show that the following are among the remarkable conclusions which have been reached by our government officials.

By the Custom House:

"1. That engineering societies, the objects of which are 'the professional improvement of its members, the encouragement of social intercourse among men of practical science, and the advancement of engineering in its several branches,' are *not* scientific societies.

"2. That the liability of a package to duty depends upon its size.

"3. That the *Transactions* of the Institution of Civil Engineers of England *are* subject to customs duty, and that the *Transactions* of the North of England Institute of Mining & Mechanical Engineers *are not.*

"4. That the *Transactions* of the Institution of Civil Engineers of England are worth about three cents each. *Sic Transit* '*ad valorum*' *mundi!*)"

By the Post Office:

"1. That while *two* cents per pound is the rate accorded to the general press, including certain pictorials about which all respectable people seem to have one opinion, a society the object of which is the dissemination of useful knowledge, must pay one cent for each two ounces and fraction thereof, or over *eight* cents per pound, on a publication issued as its own proceedings.

"2. That this Society is not entitled to 'the same low rates that are extended to the general public' under the recent law, making one cent for four ounces the rate at which an individual can post a newspaper."

The report of the Secretary was referred to the Board with power to act. On motion of Mr. C. A. Ashburner, the club rooms were unanimously tendered to the local committee of the American Institute of Mining Engineers for their headquarters.

Mr. Horace See presented copies of indicator cards from the engines of the yacht "Anthracite," taken with 370 pounds boiler pressure per square inch, and steamship "Aberdeen," with 113 pounds, also a diagram showing curve of initial pressure of steam in the high-pressure cylinder of each vessel. The cards and accompanying table showed what the division of the work between two or more cylinders, so as to

limit the range of expansion and temperature in each cylinder during one stroke, has to do with the economy of the steam engine, and that in utilizing the high pressures we must employ an engine with a degree of efficiency proportionate to the increase of pressure.

Mr. Charles A. Ashburner presented a brief description of the anthracite coal fields, accompanied by a geological map of the region, which will be engraved and published in the *Proceedings.* Among many facts relating to the geology and mining of coal, it was stated that, according to recent measurements and estimates made by the Geological Survey, less than 30 per cent. of the marketable coal contained in the high dipping beds of the Schuylkill and Lehigh basins had, during the past history of anthracite mining, been sent to market, while over 40 per cent. had been left in the mines for roof supports, and over 30 per cent. had been thrown on the culm banks as being too fine and dirty to ship. It is encouraging to know that within the last few years the 30 per cent. of actual fuel coal obtained has, in many cases, been increased to between 45 and 50 per cent.

Mr. McCreath's recent analyses show that the best coals from the Lehigh basins which can be had in the market, do not contain over 86.5 per cent. of fixed carbon, although these coals have generally been rated about 90 carbon fuels. It would appear that past analyses have been of picked specimens, while those collected by Mr. Ashburner have been samples taken from between 100 and 200 tons of the coal loaded on railroad cars ready for shipment to market. The spot value at the mines of Pennsylvania anthracite is equivalent to 92 per cent. of the spot value at the mines of all the bituminous coal mined in the United States, and 89 per cent. of the value of all the gold and silver mined in the United States.

Mr. Ashburner also presented to the Club a very fine shaded lithograph of the topography of McKean County, Pa.

Prof. L. M. Haupt added to his recent papers on rapid transit, statistics of the growth of cities as exemplified in Philadelphia.

The Secretary presented Mr. John Marston's reply to Mr. J. H. Murphy's discussion of the formula for turnouts and crossings, presented by him to the Reference Book.

The Secretary also presented the following Reference Book contributions: "A Co-ordinate Method of Ascertaining Distances in Cities, Applied to Philadelphia," by Mr. John H. Dye; "Relative Elevations of Certain Leveling Data," by the Secretary.

The Club adjourned for the summer, to meet at the call of the President.

ENGINEERING NOTES.

A New Paving Material.—The paving consists of bricks, 8 inches by 4 by 4, laid in hot tar on a bed of concrete, 6 inches in depth. In order to arrive at reliable conclusions as to the behavior of this paving material, it was laid down at the junction of the Leipzigerstrasse and Charlottenstrasse in Berlin, a spot over which the heaviest traffic passed; this was estimated at one thousand vehicles per hour, besides one thousand three hundred tramcars daily. The material appears to answer its purpose admirably. Granite, compressed asphalt, and wood pavement had been previously tried on the same spot, and had all required repair after having been down three months.

The numerous attempts hitherto made to render bricks tough and endue them with a high fracture of resistance against pressure, by steeping or boiling them in tar, have all failed, because the bitumen is unable to penetrate to a sufficient depth. In this case, however, the bricks are placed in a vacuous chamber, hot asphalt being afterwards introduced By this means the brick is freed from air and moisture, and absorbs from 15 to 20 per cent. of bitumen; it becomes very tough and elastic, is capable of withstanding great pressure, and absorbs no moisture.—*Deutsche Bauzeitung.*

These bricks have also been used for damp-proof courses, stable-pavements, retaining-walls, &c.

On the Removal of Deposit from Reservoirs in Algeria.—The reservoirs in Algeria are of great size, and they are of immense importance to the prosperity of the country; after being constructed under difficulties, and at considerable expense, they are in danger of being completely filled up, unless means are taken for the removal of the deposit which accumulates rapidly in them. For instance, the reservoir at Saint Denis du Sig, constructed with a capacity of 122,000,000 cubic feet, had in 1879 silted up to the extent of 24,000,000 cubic feet. The Habra reservoir, constructed in 1871 with a capacity of 105,000,000 cubic feet, contained, in 1879, 70,000,000 cu. ft. of deposit. The same thing takes place, but to a less extent, in Spain, and the system adopted for cleaning the reservoirs in that country is to wash them out about once in every four years. This, however, not only necessitates the emptying of the reservoir, but also causes the loss of the sediment, which is generally very valuable for irrigation. The method of remedying the evil applied by the Author at Saint Denis du Sig, consists of blowing air into the sediment, thereby stirring it up and allowing it to run off with the water. The air may be compressed by means of turbines driven by the water as it passes out of the reservoir, conducted through india-rubber pipes over the dam, and carried down into the mud by an iron tube which is attached to a float, by means of which it can be moved from one part of the reservoir to another. The Author describes the apparatus in detail, and states that as the result of an experiment on a small scale (using a 12-HP. portable steam-engine for compressing the air), the water, clear at first, became rapidly charged with the stirred-up sediment to a distance of 110 feet round the pipe. It is only necessary to inject the air near the dam, for, as the mud is removed from this position, a fresh supply flows down from the more distant parts of the reservoir, and this is in its turn stirred up into the water in a similar manner. The Author estimates the cost of an apparatus for cleansing a reservoir of the capacity of 455,000,000 cubic feet at £2,600.

IRON AND STEEL NOTES.

On the Production of Cement from Slags.—By L. Roth.—The author points out that Portland cement, and the slags obtained in the production of foundry pig-iron with coke, are essentially similar in qualitative composition, as is seen by the following analyses:—

	Cement.	Slag.
Lime	60.05	51.62
Silica	24.31	35.12
Alumina	7 50	9.53
Magnesia	1.17	1.58
Ferric oxide	3.34	—
Ferrous oxide	—	0.87
Manganous oxide	—	0 37
Potash	0.80	—
Soda	0.74	—
Sulphur	—	0.88
Gypsum	1.82	—
	99.73	99.97

In the slag, sulphur exists as sulphate of calcium, which would be injurious to the setting-power of the cement, and there is also a quantitative deficiency in certain bases. In order to supply these, the author mixes the slag with Bauxite and limestone, or lime, and moulds the powder into bricks, which are burnt in an ordinary cement-kiln, Hofmann's annular kiln being preferred. In firing, the heat is raised gradually from dull to bright redness, to drive off combined water and carbonic acid, and to convert a portion of the sulphide of calcium into sulphuretted hydrogen, and aluminate of lime; after which it is sintered at a strong white heat, and the resulting mass is crushed and ground in the usual way.

As the value of Bauxite depends upon its contents of free alumina, the proportion added will vary with its composition; the limits between which the finished product may be regarded as giving good cement are:

Lime	55 to 63 per cent.
Silica	22 to 26 "
Alumina	6 to 10 "

The proportions used by the author, with a basic slag of the composition previously given, which falls to powder when cooled, are:—100 slag, 85 limestone or chalk, with $CaCO_3$, 98, and SiO_2 2 per cent., Bauxite 15. The latter is the variety found near Giessen, which contains Al_2O_3, 48.5; Fe_2O_3, 13.52; SiO_2, 9.40 per cent.

This mixture when burnt gave 158.66 parts of cement, of the following composition:

	Per cent.
Lime	61.9
Silica	24.1
Alumina	10.6
Ferric oxide	1.3
Ferrous and manganous oxides	0.8
Magnesia	1.0
Sulphur	0.3
	100.0

One half of the total quantity of the sulphur in the slag was eliminated as sulphuretted hydrogen. The cement, when ground and sifted through a sieve having nine hundred holes to the inch, was of a greenish-gray color, and of strong hydraulic properties, showing no tendency to swell when once set. It is essential to the process that the materials should be perfectly mixed before firing. Slags that fall to pieces in the air should be sifted through a 900-hole sieve, but when they are not sufficiently basic they should be granulated in water when run from the furnace, and ground in the cement-mill. A small addition of soda may be made advantageously in some cases, but as a rule it is not necessary. The cement may be applied in the formation of articles in concrete with granulated slag, which possess a certain hydraulic character.—*Abstracts of Institution of Civil Engineers.*

RAILWAY NOTES.

The annual report of the Dominion Minister of Railways, as presented to the Canadian Dominion Parliament, shows that during the year under consideration as many as 1275 miles of railway were added to the length of road in operation in the Dominion, making a total of 8805½ miles under traffic. The railway system of Canada will within the next two years, when all the uncompleted lines are finished, comprise something over 11,400 miles. The paid-up capital has increased during the year from 415½ million dollars to 494¼ million dollars, or 19 per cent., an increase in the capital per mile completed and under construction of 17.03 per cent. The business done by all the lines in operation has grown in large proportions. The gross amount of freight carried during the year was 13,266,255 tons; and the gross receipts 21½ million dollars. The number of passengers carried was 9,579,948, and the gross receipts showed an increase over those of the preceding year of 4¼ million dollars. The net earnings were sufficient to pay approximately a dividend of 2½ per cent. on the share and bonded liability of the roads in operation.

Lartigue's Electric Railway.—M. Lartigue, the well-known French engineer, has applied electricity to the traction of the panniers or cars of his single-rail tramway. This tramway is, as we stated some time since, employed in Algeria for transporting esparto grass from the interior by the traction of camels. It was an easy step from animal to electric traction, and M. Lartigue has successfully taken it. At the recent Agricultural Exhibition in the Palais de l'Industrie, of Paris, an experimental line was shown on which five iron panniers, or double cars in the form of seats, were drawn by a dynamo-electric locomotive at the rate of seven miles an hour. The total weight of the five cars and the electric locomotive was about a ton, and the maximum power required was three horse-power. The dynamo of the locomotive was a Siemens D_6, and the generator, which stood about 100 yards from the line, was a Siemens D_2 dynamo capable of developing from 5 to 6 electric horse-power. It was driven by a Herman-Lachapelle steam engine. The total length of the line was 123 meters. It was built of forty-one rails, each 3 meters long,

and comprised curves of 7½ meters radius. The locomotive dynamo was carried by a platform car or pannier, and geared with a grooved driving wheel 30 centimeters in diameter, which ran upon the rail. A rheostat to graduate the speed, switches to stop, start, and reverse the motor, and a seat for the conductor, were also carried by the locomotive car. The train was properly coupled to the locomotive, and ran on small grooved wheels. The current was brought to the dynamo by two insulated conductors, one connected to the rail, the other to the dynamo through small contact rollers in connection with the commutator. One switch was employed to start or stop the train by making or breaking the circuit; the other to reverse its motion by reversing the current. The rheostat, by interpolating resistance into the circuit, allows the strength of the current to be varied and the speed of the train to be increased or diminished as the case may be. The work was carried out by Messrs. Siemens, and under the direction of M. G. Boistel. The economy of the working is of course largely dependent on local circumstances.

An Electric Mountain Railway.—A project has been formed, writes a correspondent, and will, in all probability, shortly be executed, for uniting the Hotel des Alpes, at Territet Chillon, and the Hotel de Mont Fluery, which is situated on the steep mountain side immediately above Chillon, by an electric railway. The difference of altitude between the two hotels is 180 meters, and the system which it is proposed to adopt was put to an experimental test recently. Rails of a gauge of 50 centimeters were laid on a part of the mountain for a length of 50 meters, and with a gradient of 30 to 100. Between the rails is a rack for the reception of a toothed wheel, and at each end is a curve in order to show the advantage of the proposed system over the funicular system, which does not admit of the slightest curve. The wagon carries a dynamo-electric machine, which actuates by special gearing a toothed wheel on the axle in connection with the rack between the rails. An electric and an ordinary brake enable the conductor to modify the rapidity of descent at pleasure. The electricity was produced for the occasion, and in the first instance, by a dynamo-electric machine of 5 horse-power, actuated by a portable engine. This engine it is intended to replace eventually by a turbine, for which there is an ample supply of water. The apparatus for the transmission of the electric force to the receiver on the wagon consists of copper cables laid between the rails and alongside the rack, and the electric contact is established through the intermediary of mechanical brushes in the usual way. The carriage, in which were seated two, three, and sometimes four persons, the whole, including the carriage, representing a weight of from 300 to 500 kilogrammes, went up the steep incline at the rate of from 1 meter to 2 meters per second, and the descent was completely controlled by the ingenious combination of the two brakes. In the event of the project being carried into effect, which depends to some extent on the approval of the federal government, the journey between the two hotels may be performed in seven or eight minutes. As, moreover, water is plentiful in Switzerland, there is no reason why every fashionable mountain should not have its own particular electric railway, and the time may come when idle or infirm tourists will ride luxuriously across the Mer de Glace and be carried on wheels half way up the Jungfrau and the Matterhorn. Already the people at Geneva, encouraged by the success of the experiment at Territet Chillon (Montreux), are proposing to utilize the waters of the Arve for the ascent of the Saleve.

ORDNANCE AND NAVAL.

The Moncrieff System.—Colonel Moncrieff read at the United Service Institution, on Friday, April 25th, to a large audience, a paper on his system of mounting ordnance. Probably many of our readers have latterly lost sight of the Moncrieff system, and have assumed that for some reason it had not fulfilled the promise of which it once appeared to be full. Some of us probably assumed that it was found inapplicable to the heavy guns now employed, or that the carriages were too complicated, or, again, that there were objections to the receivers on the hydro-pneumatic carriages. If none of these things were true it was high time that Colonel Moncrieff should call attention to this important question, which had been allowed to lapse into oblivion.

In a paper couched in very mild and moderate terms, Colonel Moncrieff explained his case on Friday. He divided the methods of mounting guns into three systems: (1) Ordinary barbette; (2) iron casemates and turrets; (3) the protected barbette or disappearing system, commonly known as the Moncrieff system. The first system—the barbette proper—exposes the men so much that it was found even in the days of the American War that barbette batteries could certainly be silenced by armor-clad vessels. Since the introduction of machine guns this operation is easier than ever. The turret or casemate system is very expensive, and the guns have, in the case of casemates, but limited scope. Consequently Colonel Moncrieff urged that his system obviously met the need of the country by providing guns which combined complete protection with all-round fire, and which offered enormous saving in money. He informed his audience that the manner in which he had been dealt with was as follows:—Successive special committees had been directed to investigate the merits of his system. He had never failed to convince a committee after a time that his system ought to be adopted; so that each committee eventually recommended its adoption. This, he said, was always the signal for the abolition of the committee. Seven committees had eventually come to the same conclusion, and had been abolished at last. Colonel Moncrieff, who was then employed by Government, was himself abolished, that is to say, his appointment was done away with, he himself being told that his services were not further required. The crowning evil was that the delay and obstruction which had taken

place have acted as a vague argument against the Moncrieff system, which it is now urged has somehow failed to succeed. The Navy had wished for the Moncrieff system, so had the Royal Engineers; the entire fault he therefore maintained lay with the Director of the Artillery Department, who refused to make the carriages, and even to buy a carriage which was to be made by Messrs. Easton and Anderson free of expense. The Colonies had asked for the Moncrieff system, which is specially suited to the case of limited numbers of men; because fewer guns are needed, owing to the fact that all-round fire is possessed by Moncrieff guns, and also that the men are very completely protected and are likely to have very few casualties. Colonel Moncrieff read a letter from General Scratchley, R.E., the adviser to the Australian Government, saying that he had always advocated the adoption of the system, and pleading that the blame of its being prevented from coming in did not lie with the Royal Engineers. It appeared that in 1872 the Moncrieff system was first approved by a committee, and for fifteen years the process of ignoring recommendations made on the score of both efficiency and economy by committees has continued. Hence Colonel Moncrieff said that he felt it needful to speak out, which he did as a man in whom all enthusiasm had been extinguished, but who had full faith that his system must eventually be adopted, although, judging from past experience, it might not be in his lifetime.

In the discussion that followed, all the speakers sided with the lecturer. Naval officers, artillery officers, and engineers appeared to be in complete accord. Mr. Anderson was called upon to speak as to the application of the hydro-pneumatic system to heavy guns, and replied that the Russians had two 40-ton guns mounted on this system, and were so highly satisfied with it that they declined to try the Albini carriage. Admiral Ryder and Admiral Sir John Hay, Admiral Boys and Admiral Selwyn, Colonel Duncan, R.A., and others spoke. It was suggested to Colonel Moncrieff that perhaps he had proved his case too clearly and unanswerably for success; he was reminded how irritating a thing this is, and he was even asked whether he could not introduce some features that would furnish his system with such faults as would make it less obnoxious and more calculated to invite sympathy.

THE "DELTA" STEAM LAUNCH.—A steam launch constructed of "delta metal" was lately exhibited at the Crystal Palace in the joint names of Mr. Alexander Dick, the manufacturer of the new alloy, and Messrs. Yarrow & Co., the builders of the launch. As it has been proved by repeated experiments that the delta metal is equal in strength, ductility, and toughness to mild steel, the plates and angle pieces of this launch were made of the same thickness as if they had been of steel, namely $\frac{3}{32}$ in. The length of the boat over all, is 36 ft., the breadth of beam 5 ft. 6 in., and the depth from gunwale to keel 3 ft., the capacity being sufficient to provide sitting accomodation for twenty-five persons. The stern, keel, and stern-post are of forged delta metal, and are scarfed together in the usual way. The angle frames are made of the same material and are placed longitudinally instead of transversely, to give greater longitudinal strength. The propeller cast in delta metal, is four-bladed, 2 ft. 4 in. in diameter, and 3 ft. pitch. The engine is of the usual direct-acting type, and of sufficient power to propel the boat at a speed of eight or nine knots per hour. The advantage of delta metal over steel and iron for shipbuilding, is that it does not rust. It is well known that a thin steel vessel, unless continually painted will rust through very rapidly. This difficulty has been found to exist to a remarkable extent in the rivers of Central Africa; in these the water, from some unexplained cause, possesses an extraordinary power of corroding and eating through steel plates. This fact is of special interest at the present moment when the rapid development of the African continent may be looked for. An important advantage possessed by delta metal for the construction of large boats, where its weight must be reckoned by tons, is that it is offered at a moderate price, and consequently the undoubted advantages of non-corrodibility are not eclipsed by a prohibitive cost.

BOOK NOTICES

MODERN HIGH EXPLOSIVES. By M. EISSLER, Mining Engineer. 8vo. New York: J. Wiley & Son, Publishers.

In the book before us we have an attempt made at editing much useful information concerning explosives.

The compiler has accumulated, from various sources, data relative to the chemical constituents and the methods of analysis which enter into the manufacture of high explosives. He treats in detail of the preparation of nitro-glycerine, the various nitro-glycerine compounds, pyroxylin, gun cotton, nitro-cellulose, and the fulminating compounds. In the second part directions are given for using the high explosives, with special reference to the various processes of firing or igniting by means of electric machines, fuses, and similar appliances. The third division of the work is devoted to different methods of blasting, including special applications in various engineering enterprises from excavating tunnels or mining shafts, to the removal of stumps and the breaking of ice. An appendix, in which various theoretical considerations will be found, brings the work to a close. The theories of explosion, as put forth by Able and Berthelot, are alluded to and commented on.

That a book of this kind is needed there can be no doubt, and we regret extremely to find in a work, admirable in so many respects, the evidences of unfortunate ignorance or extreme carelessness. The section devoted to glycerin, which is fairly representative of the book, is so filled with mistakes and inconsistencies as to be utterly unreliable. Even a cursory glance will discover many errors in chemical nomenclature. On page 15 "three hydroxyl radicals (3OH)" should be 3(OH). A few lines further on, "the oxide of a metal like lime, lead, etc.;" lead is not an oxide, and which oxide of lead is meant? Bone black is called

bone coal (p. 25). The use of final *e* in glycerin is not accepted by the best writers in chemistry, but then no attempt appears to be made to follow correct usage in this respect. Even on the first page, Chili saltpetre is first written *sodium* nitrate and then *sodic* nitrate, thus tending at the very outset to confuse readers not familiar with the ancient and current chemical nomenclatures. We find also many instances in which the editor is inconsistent with himself; for instance, on p. 12, the table of statistics foots up 9,500 tons. while directly following it is spoken of as 7,500 tons. On the same page, glycerin is said to boil at 554° F., while on page 24 it boils at 618° F., which is correct—and why are not references given? On page 13 it is stated that glycerin crystallizes at 42° F. This is novel information, and we should be glad to know on whose authority this statement is made. There are also many infelicities and ambiguities, such as the following: "Small particles of soap *conglomerate* to small lumps" (p. 18). Sentences not easy to understand: "The method which is employed depends on the *proceeding* by which the fats are decomposed and the quantitative results of glycerin on *them*" (p. 16). In the saponification of tallow by lime, it is best to use little lime; and a high pressure, for instance, by employing one hundred parts tallow and four parts of lime. Several of the latest and most improved processes of extracting glycerin are ignored entirely.

The book, therefore, is not one that we can recommend to our readers Those seeking a knowledge of the subject will be misinformed by a perusal of the volume, while those who use it for reference will find it so unreliable that they will be compelled to throw it aside as worthless. It can only be of service to such experts as are competent to separate the good from the bad, and even to them its utility will be slight. It is, however, an excellent specimen of mechanical book making, and while it evidences the good taste of its publishers, its best function will be to serve as a sample of fine printing.

STEEL AND IRON. Comprising the Practice and Theory of the several Methods pursued in their Manufacture, and of their Treatment in the Rolling Mills, the Forge and the Foundry. By W. H. GREENWOOD, F. C. S., Assoc. M. I. C. E., M. I. M. E. With ninety-seven diagrams from original working drawings. London: Cassell & Co. 1884.

This work, one of the manuals of technology edited by Professor Ayrton ahd Mr. R. Wormell, and published by Messrs. Cassell, is a comprehensive handbook of practical information, and of the scientific principles upon which the practice is based. We may at once state that Mr. Greenwood's book appears to us to be an excellent manual of the subject, which scarcely needs comment. The book is of service to the general student of the branch of technical science of which it treats, as well as to the intelligent workman, to whom it offers a succinct statement of the scientific principles upon which depends the success of the several processes in which he is engaged. The book does not—and is not intended, we believe, to—supersede the experience and practical knowledge that can be gained only in the works; but it will be found a useful adjunct to, and contribute to a clearer understanding of, these things.—*Iron.*

THE MATERIALS OF ENGINEERING, IN THREE PARTS: PART III., NON-FERROUS METALS AND ALLOYS. By ROBERT H. THURSTON, Professor of Engineering, Stevens Institute, etc., etc. New York: John Wiley & Sons.

For this volume Professor Thurston goes very exhaustively into the history of non-ferrous metals and their alloys, giving their general characteristics and their special properties. The author's very extended and carefully conducted experiments have resulted in the composition of new brasses, kalchoids and bronzes which must be of special value to workers in alloys.

WROUGHT IRON AND STEEL IN CONSTRUCTION. New York: John Wiley & Sons.

Rules for Strength of Pencoyd Iron should be properly the title of this book. Rolling mills and bridge-building companies issue "Pocket Books" of "Useful Information for Engineers, &c.," which are not simply advertisements, but contain facts and tables very useful to engineers. Pencoyd is very slow in issuing its book, which, it must be confessed is below the average standard. The book has the merit of being clearly printed on handsome paper. Pencoyd beams, channels, angles, and other shapes are set forth at great length. One might suppose that such shapes of iron had never existed before, and that a Pencoyd circle would contain a greater area than another circle of the same diameter. There is much theoretical matter in the book which is evidently very valuable in the eyes of the author, but the experiments published do not tell us what is of practical use, that is, for instance, what is the value of an angle iron, used as a strut or a tie, riveted by one leg only to its connections. The book is too shoppy and theoretical.

THE IMAGINARY METROLOGICAL SYSTEM OF THE GREAT PYRAMID OF GIZEH. By F. A. P. BARNARD, LL. D., S. T. D. New York: John Wiley & Sons.

Dr. Barnard has rendered the public an excellent service in this essay. The advocates of the pyramid metrology are urging their claims in a way that tends to deceive those who are not sufficiently familiar with the fact that figures adroitly presented may be made very misleading. The honesty of the believers in the pyramid theories presented by Piazza Smyth is not to be questioned, but the theories are, in consequence, all the more likely to deceive, and it needed the keen analysis and the pungent satire of the present volume to check the spread of this peculiar phase of fanaticism.

The essay begins with the following paragraph: "Among the many vagaries of the human mind which history records, there is not one more extraordinary than that which has been busying itself for the last twenty years in weaving a network of religious mystery around the great Pyramid of Gizeh. If it were not a

law of fanaticism that the faith of its subjects and victims is intense in proportion as its doctrines are defiant of common sense, it might reasonably have been expected that the wild conjectures, in regard to this monument, hazarded by John Taylor in 1859, would have fallen unnoticed from the press, and would long since have ceased to be remembered among men."

These conjectures, which have been elaborated by Professor Smyth, and seriously formulated into a doctrine, affirm in general terms—that the Great Pyramid was built by Divine direction, and that its various dimensions reveal, when rightly interpreted, the size and density of our globe, the solar distance, and the length of the year; also exhibit quite accurately the periods of time separating the important crises of sacred history.

As the length of the base of the pyramid affords the starting point for numerical comparison, and as there is a remarkable lack of agreement in the measures thus far obtained, Prof. Smyth has adopted a number lying between the extreme results, but which is not a fair average of the measurements, nor does it agree with any one of them, but it fits the theory, and is supposed to be, therefore, worthy of adoption. There is much of this kind of dealing with numbers among the pyramidists. Sometimes the measurement of the pyramid is made to adapt itself to the requirements of the theory, and sometimes it is the so-called *revealed* dimension or date that suffers the strain. An example of this latter kind is afforded in a proposition of Professor Smyth's, which runs as follows:

Multiply the tenth part of the cube of the ten millionth part of the earth's polar diameter by the mean density of the earth, and the product will give the pyramid unit of capacity. (The presumed original capacity of the sarcophagus.) Dr. Barnard says of this, after presenting the figures, "The arithmetical coincidence is exact; but we shall see that this extremely satisfactory result is only owing to the happy selection of a value for the axis of the earth, which no computer has ever found, and of a number expressive of the earth's density, which no investigator of that subject has ever reached."

Coincidences of like kind are numerous in the standard work of the pyramid followers (*Our Inheritance in the Great Pyramid*), and the principal ones are analyzed in like manner.

If anything could exhibit the absurdity of the doctrine here criticised in a stronger light than the exposition of the method of establishing it, it is the satire embodied in Dr. Barnard's suggestion that a similar manipulation of figures exhibits the lunar theory in the temple of Ephesus, and the base of the hyperbolic system of logarithms in the base of the Great Pyramid.

Dr. Barnard's essay will be widely read, and most readers will learn with surprise that men eminent in science and literature have been misled by the doctrines that are therein so effectively analyzed.

DRAINAGE AND SEWERAGE OF DWELLINGS. By Wm. Paul Gerhard. 12mo., 302 pp. New York: Wm. T. Comstock. Price $2.50.

It is always fortunate when a man eminently successful in a large practice is able and willing to write his views and methods clearly, and give them to the world in a book. Mr. Gerhard has made a book on an immensely important subject, which sustains the reputation he had before earned by his masterly report on this subject to the Rhode Island Board of Health: We define a practical man to be one accustomed to successfully doing the work. Mr. Gerhard is now actively employed as chief engineer of a company making a speciality of draining houses and populous districts.

It is not easy to find a polite descriptive adjective for the man or men who first ventured to take a privy into the middle of a first-class dwelling-house. Lazy is a weak term, and effeminate is a slander on the sex. His faith was strong—faith in the efficiency of water and traps which experience and the loss of many lives has shown to be misplaced unless more care and skill than usual are exercised.

This book by Mr. Gerhard seems to go far towards undoing the mischief. It does not, like too many, spend all the strength of the writer and the patience of the reader on the evils to be avoided, but diligently and patiently labors to show how to avoid them. It is liberally illustrated with sections showing the arrangements and devices in general view and in detail. Traps old and new are dissected profusely.

We are particularly pleased with Chapter II., "Necessity of Ventilation in Rooms containing Modern Conveniences," Chapter VIII., "Drainage of Cellars," and Chapter X., "System of Internal Sewerage as it should be in a Dwelling." The work should meet with an extensive sale.

A PRACTICAL TREATISE ON ELECTRIC LIGHTING. By J. E. H. Gordon, B. A., M. S. T. E. Sampson Low, Marston, Searle and Rivington, London. 1884.

It seems to us that the author of such a book as this should treat his subject under heads, his principal heads being: (1) generation; (2) distribution; (3) utilization, and (4) tools; the sub-heads may be as numerous as the author chooses. With regard to the generation of electricity little need be said of batteries; but some attempt might be made to explain the great similarity of the various dynamo machines. They are easily classed under a few types. The continuous ring armature type includes such as the Gramme, Burgin, Brush, Schuckurt, &c. Then we have the Siemens armature type, alternate current machines, and so on. Starting with a full and complete description of the typical machine, the various modifications, the reasons for their introduction and the gains by introduction could then be successively discussed. However, it is generally admitted that, according to their own showing, most reviewers would make admirable authors. Unfortunately, when they attempt to carry into practice the views they put forward, the result is frequently a miserable failure. We shall therefore return to the real subject of this notice, showing that Mr. Gordon has, to some extent, carried out these views. After an introductory chapter on the

principles of artificial lightning, he shows the analogy between a fluid, such as water, and electricity. Although we think the way in which Mr. Gordon has introduced these analogies to be exceedingly instructive, we must not forget the caution of Clerk-Maxwell when warning his readers against the use of the term "electric fluid."

The aim of those who desire to produce artificial light economically is thus stated, p. 8, "to concentrate the heat in a solid of the smallest possible size, or with the smallest possible cooling surface." How this is done in electric light operations it is the business of the book to show. Whenever a new application of science is developed, it becomes necessary to show how the principles of the science are used in the development. Practical work needs systems for measurement, practical units of measurement, notation, and so on—a branch of the subject to which Mr. Gordon devotes some of the early chapters of his book. In these he discusses the relation of the electrical units with one another, and with the units of heat and work. The electrician finds nothing new herein, but the electrical engineer will here see the arithmetic of his work. The formulæ he has to use are collected and illustrated. Here, too, are some interesting comparisons, showing the value of the commercial electrical unit in various measures, and we are given a rule for the comparison of the prices of electricity and gas. Thus: "To compare the price of electricity with that of gas, we must multiply the price per electrical unit by 10, and the result will be the price of a quantity of electricity approximately equal in illuminating power to 1,000 cubic feet of gas."

Electricity—to use an ordinary expression—generated for electric light purposes is utilized by means of lamps. The different incandescent lamps are, in the first place, described, and their method of manufacture, the details being given and amply illustrated. Then the best known types of arc lamps are described. The requirements for the lighting of particular places are discussed, and it is shown how the lamps and other apparatus must be designed for the purpose in view. A very interesting chapter, for which the author states his indebtedness to Mr. Crompton, on carbons for arc lamps, is given, and then we come to that portion of the book dealing more directly with the generation of the current. Besides being a writer, Mr. Gordon is an inventor, and professes to follow the example of Cumberland, Maskelyne, and others, in "telling how it is done." We doubt, however, if the readers can invent, after reading this book, any more than the hearer could perform the tricks shown at St. James's Hall after hearing how they were done. Indeed, the telling is simply reduced to this: Mr. Gordon has by a process of reasoning come to the conclusion that a certain type of dynamo is the best, and he forthwith sets to work and designs such a dynamo. Now we are inclined to think that there is more than one road to travel in order to get to a new design of dynamo; and we are not at all sure that Mr. Gordon's explanation proves that his road is the best. However, there is no doubt that he puts forth the principles of magnetic induction and of the best-known machines in a clear and concise manner. All this part of the book is exceptionally worthy of close study. It abounds with hints of a very practical nature, and points out what not to do in many cases.

Before concluding this notice a word of praise should be given for the excellent illustrations and typography of the book.—*Abstract of Review in Engineer.*

MISCELLANEOUS.

The riches of the United States from gold and silver mining may be partially estimated by the fact that the aggregate production of gold up to June 30, 1883, has been 1,632,364,-670 dols. That of silver has been 598,083,217 dols., making a grand total of 2,230,447,887 dols., or £446,089,577. Reduced to the equivalent weights, the total gold output has been 78,965,572 troy ounces, or 2707.4 avoirdupois net tons, while the silver weight represents 462,590,469 troy ounces, or 15,860 tons. Putting the statistics into another form, the gold produced in the country up to the present time, if brought together, would be sufficient to load 271 ordinary freight cars; the silver, supposed to be collected as fine bullion, would require 1586 cars for its transportation. The gold would tax the carrying capacity of a large ocean steamship, while the silver would form cargoes for a considerable fleet.

The distances, often many miles, through which gas is transmitted before reaching an engine, are such that, with any other means of distributing power, they would considerably enhance the cost of the power. But in the case of gas, it does not appear that these distances are at all a matter of consideration. Professor Osborne Reynolds thus explains this:—It takes about ten cubic feet of gas to develop 1,000,-000 foot-pounds in a gas engine, whereas of air compressed in the ordinary way, it would require something like 140 cubic feet to yield the same power. Hence the comparative cost of transmission is the cost of transmitting ten cubic feet of gas against that of 140 cubic feet compressed air, and these would be about as one to twenty-five; so, as a means of distributing energy, gas is twenty-five times more efficient than compressed air.

Professor Foster recently read a paper, before the Physical Society, by himself and Mr. Pryson, on the difference of potential required to give sparks in air. Let V=this difference of potential, l=length of spark in centimeters, their experiments give approximately $V=102l+7.07$. Tables and curves of the sparking distances, potentials, and electric forces in the experiments were given. The results were got with brass balls 1.35 centimeters in diameter, a friction machine, and a Foster absolute electrometer. When l=.142, the electric force giving a spark was 154.76; l=.284, the electric force was 133.35, or less than at a shorter distance; l=497, the electric force was 131.66; l=.9, the electric force was 138.57, that is, it began to rise again.

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ANALYSIS OF A ROOF TRUSS.

By Prof. DeVOLSON WOOD.

Contributed to Van Nostrand's Engineering Magazine.

In the course of my instruction frames like Figs. 1 and 2, have occasionally been

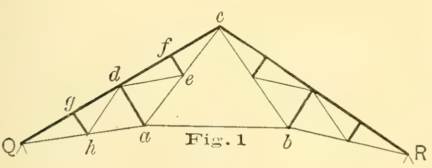

Fig. 1

analyzed graphically. It will be seen that the chief difference in these frames consists in the position of the horizontal tie;

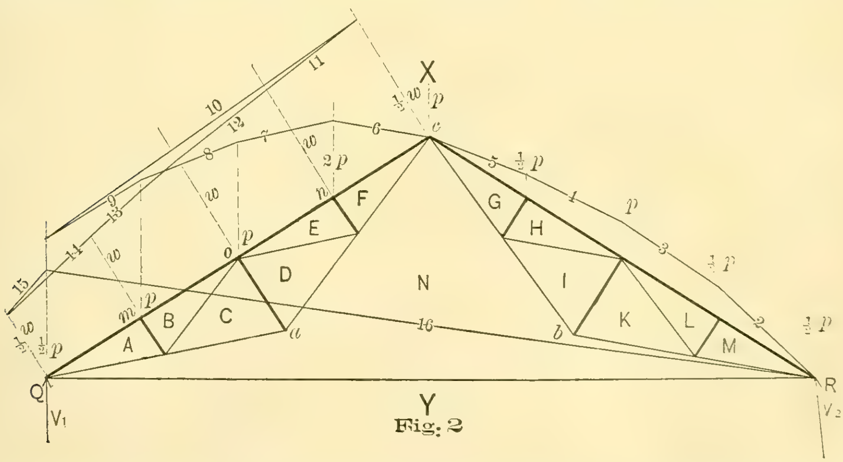

Fig. 2

in Fig. 1 connecting the points a and b of the secondary truss, while in Fig. 2 it joins the lower ends of the long rafters. In Fig. 1, after finding the reactions of the supports, the analysis proceeds without difficulty until the joint a or d is reached, where three unknown stresses meet. To pass these points various methods have been devised.

This frame is analyzed in the Graphical Statistics of Du Bois, and also in his later work—"Strains in Framed Structures;" and I remember seeing a solution, some years since, in an English journal, I think in *The Engineer*, in all of which there is a resort to a special artifice. In the two former works, the stress on de due to the load at f is found, which reduces the un-

known stresses at *d* to two, after which the analysis proceeds without difficulty. In Fig. 2, three unknown stresses meet at Q and R, so that the analysis of internal stresses cannot begin at these points unless the stress on the horizontal tie be first found. This frame may be analyzed by finding the stress on the secondary parts first, and thence passing to the primary parts; but we have generally sought the stress on the horizontal tie directly. Various methods were resorted to, until, at last, I conceived the idea of using the equilibrium polygon, for this purpose, which gave not only this stress, but also the stress at the apex *c*. I can hardly presume that this use of the equilibrium polygon is new, although I have no knowledge of its having been so used by others. The process is so distinct, and the results so satisfactory that we have used no other method since it was devised.

For the purpose of illustrating and explaining the principle, I have assumed that the frame in Fig. 2 is loaded eccentrically, by weights $\frac{1}{2}$ *p* at Q, *p* at *m*, *p* at *o*, 2 *p* at *n*, *p* at *c*, and so on with $\frac{1}{2}$ *p*, *p*, $1\frac{1}{2}$ *p*, $\frac{1}{2}$ *p*, the last being at R; and also a wind pressure normal to Q*c* of $\frac{1}{2}$ *w* at Q and *c*, and *w* at each of the joints *m*, *o*, *n*. $n=\frac{1}{4}p=1{,}000$ lbs.

Assume that the frame is hinged at R and free at the support Q, then will the reaction at Q be vertical. In Fig. 3, construct a force polygon, or so much thereof as possible, with the known forces; TP for the wind pressures, PU the vertical weights, and a vertical through T to represent the reaction V_1, the length 7 which remains to be determined. From any assumed pole O, draw the radial lines in the well-known way, by means of which construct the equilibrium polygon in Fig. 2, *beginning at* R *the point of application of the force* V_2, *whose magnitude and direction are unknown.* The radial line 1, Fig. 3, does not appear in Fig. 2, for it cuts V_2 and $\frac{1}{2}$ *p*, both meeting at R. The other lines are numbered the same in both figures. The last line in Fig. 3 is 15, but in Fig. 2 the polygon must close, which is done by drawing 16, after which 16 in Fig. 3 is drawn parallel to that in Fig. 2. The line 16 in Fig. 2 cuts V_1 and V_2; hence S Fig. 3, where 16 cuts the vertical TS, is the common point of V_1 and V_2; and TS will be V_1, and US will be V_2 in magnitude and direction. TPUST is the polygon of external forces.

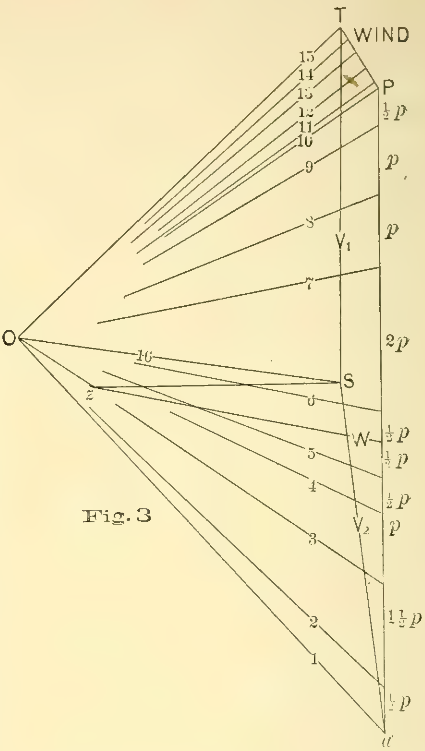

Fig. 3

The magnitude and direction of the force at the joint *c* is unknown; to find which conceive a vertical plane passed through the point and the left half of the frame unmoved. Make, as before, as much of a polygon of forces as possible with the forces known as acting on the right half of the frame—which are $\frac{1}{2}$ *p* at *c*, then $\frac{1}{2}$ *p*, *p*, $1\frac{1}{2}$ *p* $\frac{1}{2}$ *p*, which last is at R, and V_2 previously found. The several weights *p* are laid off from W to U Fig. 2, and US$=V_2$ as before found, and SZ of undetermined length, horizontally through S will represent the direction of action of the stress in the horizontal tie. Using the same pole as before, construct an equilibrium polygon, *beginning at c the point of application of the force whose magnitude and direction of action are unknown.* In this case it so happens that the first equilibrium polygon passed through *c* so that the last named polygon will coincide with the former in part. It will begin at *c* and end at R; hence the

closing line of the polygon will be Rc, coinciding with the main rafter; and OZ Fig. 3, parallel to Rc will intersect the horizontal force at Z, therefore ZS will represent the stress in the tie RQ. The line ZW, joining Z and W, will represent the stress at c in magnitude and direction. The force polygon for this half of the frame will be WUSZW. Had the other half been taken, the force polygon would have been TPWZST, or the same result would have been found.

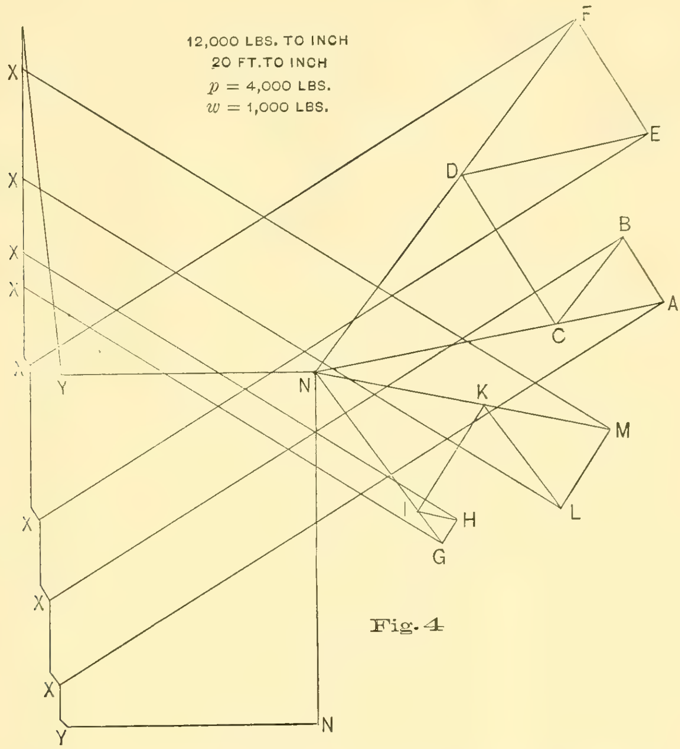

Fig. 4

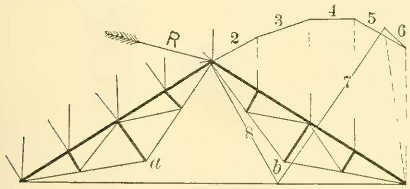

Fig. 5

Now the analysis of the other internal stresses may begin at Q,R, or c, and proceed in the usual way, the results of which are given in Fig. 4.

Had the pole O, Fig. 3, been taken at Z, the equilibrium polygon, Fig. 2, would have passed through c and terminated at Q so that the closing line 16 would have coincided with QR, and in Fig. 3 would have been ZS; in which case the stress in the tie QR, the oblique stress at c, and the two reactions would have been given by one construction.

If the first equilibrium polygon, starting at R, does not pass through c, it will be necessary to construct another. Figures 5 and 6 show such a construction.

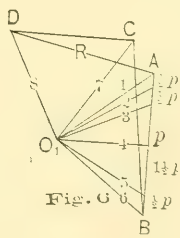

Fig. 6

These are for the same problem as Fig. 2, but the scale of the figures are one-

fourth the size. In Fig. 6, AB=WU of Fig. 3; BC=US; but the pole O_1, Fig. 6, is in a different relative position. The equilibrium polygon 2, 3, 4, 5, 6, 7, of Fig. 5, corresponds with the pole diagram of Fig. 6. The line 8 of Fig. 5 is the closing line of the polygon, parallel to which is 8 of Fig. 6, and the latter by its intersection with CD determines the point D. Then will DC=ZS of Fig 3, and DA=Z W; and the remainder of the solution will give Fig. 4.

ON THE ALTERATION OF MINERAL COAL BY EXPOSURE TO THE ATMOSPHERE, TOGETHER WITH A NEW METHOD TO PRESERVE IT.

By FRANZ POECH, ant. Mining Engineer, Vienna.

Translated by JOHN P. WISSER, First Lieutenant, First Artillery, U. S. Army.

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It is well known that mineral coal, especially the less compact lignites, holding much water, crumbles gradually by exposure to the air for some time, and the finest and most valuable pieces are gradually converted into rubbish and dust. Bituminous coal is less liable to crumble, but loses by exposure in calorific power, and those varieties applicable for the production of coke lose the power of coking. Most mineral coals have a tendency to ignite spontaneously, and many a coal depôt has already been destroyed by this action.

An effectual method for the prevention of alteration and the spontaneous combustion of coal would therefore be of great value to coal producers, who are often compelled to store coal in enormous masses.

How sensibly the value of coal is diminished by long storage is shown by the following example:

From a heap of stored Bohemian brown coal, medium coal I, which lay exposed 5 weeks, only 60 per cent. of this grade could be obtained in the re-sorting before shipping; the other 40 per cent. was converted into nut coal and dust.

The 40 per cent. removed by alteration lost in value $\frac{15}{6}$ kreutzer* per hundred-weight, from which the calculated loss for the entire quantity of stored coal amounts to 4.3 kr. per hundred-weight, the cost of re-sorting included.

The loss to coal works, caused in this way, is therefore considerable; a work in north-west Bohemia hardly makes 4.3 kr. per hundred-weight of coal. Moreover, the loss increases in direct proportion to the time of storage, and cases may be cited in which 80 to 90 per cent. of the coal deposited was altered by exposure.

Mining-Engineer Wenzel Poech, in Karbitz, has discovered a simple, cheap, and practicable means of preserving piles of coal. It consists principally in leading steam into the coal pile, thus excluding the air and moistening the coal uniformly.

Before proceeding to the description of the process I will discuss briefly the chemical and physical phenomena attending the alteration and spontaneous combustion of coal.

Porous bodies, it is well known, have the property of absorbing gases. This is seen in platinum sponge, which condenses so much air in its pores that the heat produced will cause hydrogen, directed against its surface, to combine with the oxygen and form water. It is also seen in charcoal, one of the most porous substances, representing, as it were, the skeleton of the wood mass. According to the experiments of Saussure, charcoal absorbs 9 times its volume of oxygen, and 35 times its volume of carbon dioxide.

Mineral coal also possesses a porous structure, and Saussure has shown that it absorbs three times its volume of oxygen.

According to Fayol,* the absorption

* 1 Florin (Gulden) =100 kr., is now worth about 42 cents.

* Comptes rendus de la société de l'industrie minérale, 1882, page 74.

power of all coal, from anthracite to lignite, is 5 to 10 per cent. by weight.

The property possessed by porous bodies of absorbing gases is a surface action. The walls of the pores attract the gases, just as water is drawn into narrow tubes. This has not been proven conclusively, but there is good ground for making the assumption; moreover, the hygroscopic power of a substance is taken as the measure of its absorbing power.†

While all other gases absorbed by coal remain unaltered, oxygen is condensed and combines with the carbon and hydrogen, producing heat.

Varentrapp‡ has shown that brown coal oxidizes in a current of air of less than 50° C. temperature, and that the amount of oxygen absorbed, although small, is nevertheless increased by an elevation of temperature, and may result in the complete consumption of the carbon without producing ignition.

E. Richters§ determined the fact that fresh, dry bituminous coal will absorb a considerable amount of oxygen in a few days, without giving off any carbon dioxide and water, and that these oxidation products remain condensed in the pores of the fuel. The latter circumstance offers no impediment to the absorption of oxygen, this only ceasing when the disposable hydrogen and the easily oxidized part of the carbon are combined with oxygen.

At normal temperature the absorption of oxygen proceeds until the complete oxidation of the easily oxidized constituents; hereby carbon dioxide may be given off, but at higher temperatures both carbon dioxide and water are driven off.

In case the absorption takes place slowly, so that the heat produced may be disseminated, and no appreciable rise in temperature results, hydrogen and oxygen remain condensed in the pores; only in the contrary case are they expelled, and new oxygen absorbed, new quantities of heat produced. Through the increase of temperature, however, an energetic chemical action takes place between the oxygen and the combustible material of the coal, the result of which is finally spontaneous combustion.

Coal dust does not absorb more oxygen than coarse granular coal, but the absorption, in consequence of the larger surface presented by the dust, proceeds much more rapidly, and herein, together with the difficulty of furnishing the coal dust with sufficient fresh air to carry away the heat, lies the cause of the more easy spontaneous combustion of coal dust.

According to Fayol the temperature of ignition of lignite, in the form of powder, is 150° C., of anthracite, 300° C.

The causes of the crumbling of coal by exposure are manifold. In all probability it is due to the absorption of oxygen and the resulting carbon dioxide, which, being compressed, must exert a pressure on the walls of the pores. Possibly, also, by the chemical reactions, a body is disturbed which hitherto acted as cement.

Of great importance, directly or indirectly, in this connection is the circumstance that the hygroscopic moisture evaporates after a certain time, leaving the fine cracks and pores free for the penetration of the oxygen of the air, for which there is thus furnished a larger surface for its action.

Now, the escape of the hygroscopic water cannot take place without the production of mechanical alterations, as may be seen in the similar action of the warping of drying wood, or in the cracks of a dried swamp; hence the cracking and crumbling of stored coal through chemical action will be facilitated if the pores are first deprived of their protecting water.

A means which prevents the escape of the original mine moisture must be of the greatest benefit in preserving it. As will be shown more in detail further on, this can be accomplished in a simple manner by immersing the coal in water, or in an atmosphere of steam, since the mechanically held water will not escape in this case, and the passage of oxygen into the pores be prevented. By keeping the coal constantly moist or by steaming it, aside from the fact that the air is also externally excluded from the pieces of coal, the oxidation and alteration may be effectually opposed.

Brown coal loses little in calorific

† Dr. F. Muck, Grundzüge und Ziele der Steinkohlen chemie, page 81.
‡ Johresberichte der chemie, 1865, page 837.
§ Johresberichte der chemie, 1869, page 1120.

power by crumbling, but considerable in commercial value. In bituminous coal, as a rule, the yield of coke in coking, and of gas in dry distillation, suffers considerable loss. Gas works prefer the newly-mined coal, as is quite natural, since the disposable hydrogen, so valuable in gas making, is the first to be oxidized by the absorbed oxygen.*

In regard to the part played by iron pyrite in the spontaneous combustion of coal, the following remarks may be made:

The view that only coals containing pyrite or marcasite are subject to spontaneous combustion, must be abandoned, since the observation has been continually made that often the coals free from pyrite have the greatest tendency to spontaneous combustion.

Fayol, who studied this question thoroughly and conducted careful experiments, remarks in this connection:

1. The first and greatest cause of spontaneous combustion is the absorption of oxygen by the coal.

2. The most favorable conditions for the self-heating of coal are a mixture of pieces and dust, an elevated temperature, a large mass of coal and a certain volume of air.

3. Large pieces, low temperature, small volume, and the complete absence of air or good ventilation, act in opposition to self-heating.

4. In general pyrite plays only an unimportant, mostly insignificant part in spontaneous combustion.

5. Mechanical forces, or the heat produced thereby, cannot be assigned as the usual causes of the burning of coal mines.

Durand assumes that when the sinking roof of a gallery concentrates the entire pressure in a few places, considerable elevation of temperature may be thereby produced.

In order to investigate the effect of pyrite in elevating the temperature, Fayol carried out many experiments by placing pulverized coal, coal and pyrite in an air bath at 100° to 200° C., allowing them to remain some time, and observing the increase in weight and temperature.

* The "Journal fur Gasbelenchtung und Wasserversorgung," 1884, page 232, cites a case in the Nettlesworth coal, which, after six months' storage, had crumbled to dust. The yield of gas fell from 29 m^3 to 27.

He succeeded in showing that pyrite oxidizes less easily than coal (in the air bath at 100° C. the samples of coal took up 7 per cent. oxygen in three months, pyrite only 4 per cent.), and that the addition of pyrite to the coal even retards the increase in temperature. The results of the experiments of Fayol confirm the older work of Richters, but are less complete, in that they have reference only to the air-dried condition of the coal.

That the relation of pyritiferous coal to oxygen is different in presence and in absence of moisture, the experiments of Richters have conclusively proven.

This investigator found by direct experiment that pyritiferous coal, kept constantly moist, absorbs twice as much oxygen as in the dry state. The moisture accelerates the decomposition of the pyrite, and induces further chemical processes, such as the formation of salts, the absorption of water, etc., by which again heat is produced. In order that the moisture may cause this action a sufficient amount of oxygen is necessary.

Moisture, as a rule, rather retards than accelerates the production of heat, and only under peculiarly favorable conditions, and in presence of much pyrite and a sufficient volume of air is it capable of promoting the alterations.

Hence, neither pyrite nor moisture nor mechanical power appears capable, in general, of causing the burning of mines, and, in by far the greatest number of cases, the cause of spontaneous combustion can only be found in the absorption of oxygen.

If the coal is placed in an atmosphere of water vapor, which excludes the atmospheric oxygen from the coal, the hygroscopic water will have no tendency to leave the pores of the coal, nor can a chemical action set in, even in presence of pyrite, the oxidation of which is, under other circumstances, essentially promoted by the presence of moisture.

It is therefore not to be doubted that, by displacing the oxygen and keeping the coal moist, alteration and spontaneous combustion may be checked. A complete immersion would meet the requirements, but would only be practicable in rare cases; irrigation alone would not be perfectly successful.

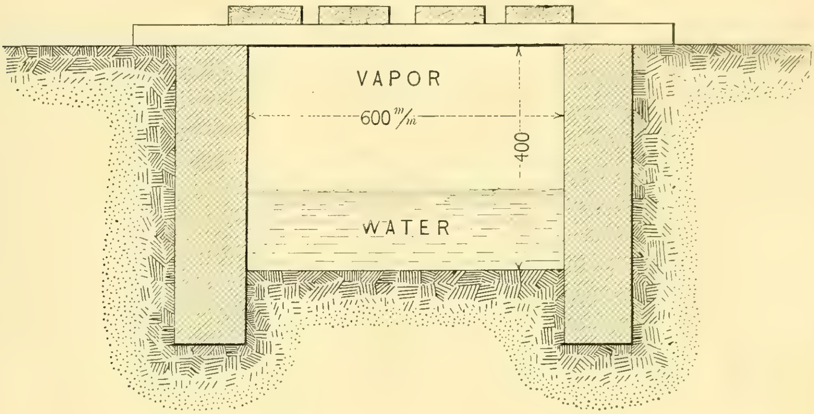
Wenzel Poech excludes the air and produces a uniform wetting of the stored

piles of coal, as already mentioned, by admitting spent steam into the depot pile.

For this purpose a series of trenches are cut in the depôt ground, as shown in cross section here; they are so covered with beams and boards that narrow spaces remain, not large enough to permit the coal to fall through.

coal to be stored and the height of the pile; for medium-sized coal the distance between the canals, with a height of pile equal to 3 m. is 3 m.

The exhaust steam of a steam-engine of 4*e*, which was worked for but six hours during the day, was entirely sufficient for the preservation of a depot of 20 car-loads of coal.



The boards are simply laid on cross pieces, are not fastened, and can be easily removed for the purpose of cleaning out the trenches.

On the ground thus prepared the coal to be stored is deposited in the usual way, the trenches are then connected with the exhaust-pipe of a steam-engine, and the steam admitted; it passes through the interstices in the covering into the coal pile, disseminates itself through the latter, displaces the air, and in consequence of the condensation of the vapor moistens the coal uniformly.

In order to effect a uniform distribution of the vapor it is necessary to cover the coal depot with fine coal and cinders, as in the case of charcoal heaps; thereby strong draughts of air will also be prevented from passing through the pile and interfering with the equal distribution of the steam. In case of coal containing little pyrite, careful covering of the pile is not so necessary, but is of importance in case of coal rich in pyrite.*

The width of mesh of the network of canals which exists in large depot grounds depends upon the size of the pieces of

* This should be confirmed by determining first whether the covering of the pile, by preventing the escape of the heat developed by the condensation, may not be harmful.

In carrying out the process it was repeatedly shown that the losses sustained in the purely mechanical movements, in the pouring out at the unloading of the coal, are far smaller than they are usually assumed to be, and that in this assumption a large portion of the waste produced by alteration was attributed to the destruction by the pouring out.

In the loading of the coal preserved by steam it was found invariably that only in the locality where the first unloading took place, and where the coal fell from greater heights, attrition took place, the rest of the coal was good, was well preserved, and could be loaded without re-sorting.

The cost of construction of the trenches and their coverings—for which latter old and otherwise useless boards, beams and road-beams of the mine are utilized—for a depot for 100 car-loads of coal amounts, at most, to 30 florins.

The cost of working is nothing, and the outlay consists only of the cost of preserving the trenches, and the interest and amortization on the applied capital.

Results relative to the use of this process have been obtained at the following works:

"Exc. gräflich Nostiz'scher Maria Antonia" shaft, near Karbitz.

"Ferdinand" shaft, near Teplitz.

"Bruno" mine, in Weisskerchlitz, near Teplitz.

At the Maria Antonia shaft, in consequence of the thankworthy permission and support of "Bergdirector" J. Neuber, the manager, Wenzel Poech was enabled to make the first experiments, and since then the process has been in full working order.

At the Ferdinand shaft, belonging to the Austrian Coal Industry Association, confirmation of the described preservation method was quite accidentally found; over a reservoir, covered with debris, and into which exhaust steam passed, coal had been deposited, which, on reloading it, was found to be perfectly preserved.

According to communications from mining engineer Hans Gutmann further experiments were carried on with favorable results, and the working of the process on a larger scale was proposed.

The Director of the Bruno Mine, Em. Baier, uses old gratings to cover the canal; he also subjected coal, without covering with cinders, for more than two months to exhaust steam, and found it in no way altered.

To insure a uniform production, and with reference to the increasing losses at the works, it is much to be desired that this process may prove completely successful, especially as the methods formerly used proved worthless.

The usual insertion of wooden tubes and the production of canals in the coal pile is directly detrimental, since oxidation is thereby only favored; investigation has also shown that at the surfaces of contact between the walls of the tubes and the coal, the latter is most liable to spontaneous combustion, so that now, on the contrary, the tendency is to level the coal as compactly as possible.

I arrive, therefore, at the following conclusions:

Freshly-mined coal, deposited on the rubbish piles is capable of condensing several times its volume of oxygen in its pores. The oxygen absorbed enters into chemical combination with the easily oxidized constituents.

According as the absorption is rapid or slow, a greater or less elevation of temperature is produced. In the former it may lead to spontaneous combustion.

The crumbling of coal is, among other causes, a consequence of the absorption and condensation of oxygen in its pores, and the chemical changes taking place. The escape of the hygroscopic moisture favors the absorption of oxygen.

The pyrites can only produce a furthersome effect on the increase of temperature when present in considerable quantities, and then only in presence of moisture and air; in the dry state they must be regarded as perfectly passive, and may even be detrimental to the warming.

Freshly-mined coal placed in an atmosphere of steam can suffer no change. Even with incomplete exclusion of the air the steam will, in general, oppose oxidation and warming, principally by uniform moistening of the pieces of coal.

THE CONSTRUCTION OF IRON VESSELS.

From "Iron."

The following paper, on "The Construction of Iron Vessels and the Board of Trade Rules in regard to the Safety of Ships and the New Shipping Bill," was read on May 8, at the Inventors' Institute, Lonsdale Chambers, 27 Chancery Lane, by Mr. S. J. Mackie, C. E.

If we regard the whole of the controversies which have been so hotly waged between the President of the Board of Trade, the shipowners, the shipbuilders, and the mariners, can we rise from the contemplation and feel that the roots of the evil have been really reached? Or, that the responsibilities tried to be thrown on shipowners are such as ought not to be properly shared at least by the Board of Trade? The position of shipowners with regard to governmental control ought to be either entire responsibility within well-defined limits, or entire absence of responsibility by compliance

with governmental requirements. Whatever the shipbuilders have done amiss, the Board of Trade has done worse! In fact, in this case of safety of ships at sea, the Board of Trade rules have prevented safe ships from being designed, and have offered a distinct premium for the building and sending to sea of unsafe and untrustworthy ones. Let the Board of Trade revise and alter its own rules, and there will be little need for other legislation. It will not be in the interest of shipowners to own dangerous vessels, if they can get safe ones to be built upon anything like equal terms. The severe inequality of the existing terms are solely due to the rules of the Board of Trade. There are points to be brought out. What really is the condition in which we find the ships of our mercantile marine? Look at the newspapers from day to day under the heading of "Wrecks and Casualties," and for the various accounts of vessels run down in collisions or broken up on going ashore, or capsized from shifting of cargo! Ought an iron vessel to go to pieces when she goes ashore? Or, if properly constructed, ought she not to rest there, and resist the battering of winds and waves until a high tide admits of her release? Ought an iron ship to sink in so few minutes after a collision on the broadside that there is not time to rescue even her crew—still less time to rescue her passengers if she carries any? Ought any sailing ship to capsize if properly designed? Ought a steamer's shaft ever to break by twisting, or engine bearing ever to get hot, as they frequently do, through the strains of a badly constructed hull? These are questions which a knowledge of existing inventions would speedily reply to, and are conditions which, if required to be fulfilled, inventors would quickly answer! Let us go no further than the Thames, and we shall see river steamers built to the requirements of the Board of Trade, and approved by surveyors, having the middle body entirely undivided, with all the dead weight of the engine in it, and only $\frac{1}{4}$-in. iron skin to keep out the water! Such a vessel being hit amidships, what would be the result? We know it by the Princess Alice. The dead weight of the engines and boilers would tend by gravitation to sink; but the buoyancy of the ends would cause upward pulls, the combined action tending to increase the gash and to pull the hull asunder. Is this a fit vessel to carry passengers by the hundred on a river busy with tidal, steam, and sailing traffic? Common sense says "Certainly not." But the Board of Trade sanctions such steamers, not only for the river, calm and smooth, but for service on the boisterous seas! Does anyone conceive that the surveyors of the Board of Trade don't know such vessels to be unsafe? Assuredly they must know it; but will the Board of Trade permit the interference of its officers? The Board of Trade declines responsibility, but it does not decline to enforce its antiquated rules upon the designers of ships—rules neither founded on arithmetic nor honesty, but which fudge the tonnage of the ship, and risk the sailors' lives, to save the owners' pockets in dues to be paid? Are not harbors and lighthouses, whether English or foreign, worthy of their tolls for their services to shipping without being cheated of their dues by rules of measurement, which give dangerous vessels the advantage over safe ones? These rules have been handed down from our grandfathers, who had wooden vessels, and kept the carrying trade of the world in their hands. So it is that still, by the breadth and half breadth and other complications, the Board of Trade rules bring about the calculated result, that a rectangular box swum one way in the water will carry more upon the same displacement of water, than it will if swum the other way—which is nonsense. In the olden time it gave the shipowner a governmental certificate far below the carrying capacity of his vessel, and consequently his ship's dues were less than they ought to be whenever he had to pay them. These rules do the same thing now for the modern iron ships and the modern shipowner. But note what has been the effect of these rules upon the naval architect, the designer, and the contractor! The ancient shipowner regarded that man as the best architect who could produce a sea-going vessel which could carry her cargo best on the same tonnage measurement by Board of Trade rules. Hence we have in the stated details of vessels, "tonnage registered" as distinct from "displacement." The naval architect has almost disappeared. Ship-

builders have become ship designers, and cheap ships have become as cheap houses. Shipowners think most of the firm who can get most cargo into a ship of the same registered tonnage. It is only to know what is the fundamental principle of this dodge to comprehend at once how its application must produce the worst sailing and the worst steam vessels, as well as the most dangerous, the more fully it is employed and carried out. There is no form of vessel or receptacle that will carry more than a square box. Hence the direct outcome of the Board of Trade rules is the square midships section. Now, floated in the water there is no form more unstable. It capsizes naturally, and load it uniformly, or how you will, the tendency to capsize is always there. It is innate, and can never be got rid of. The square midship section, then, is the dodge—the instability of the ship is the result. The old wooden vessels had a reserve of buoyancy in the thickness and lightness of the material of which they were constructed, and waterlogged wrecks were not uncommon. There are no waterlogged iron, single-skinned vessels, and one reason why steel is preferred to iron is that that material can be prepared thinner and lighter, and so add to the carrying capacity of the hull. But the thinness of the material adds also to the danger of those on board, who have to traverse the seas in sailing vessels. Sailing ships have to be varied in depth in proportion to the sails they carry. The sailing ship practically is a pendulum, the weight upon the bottom of the hull bringing the sails upon the mast against the pressure of the winds. The sailing ship, therefore, must cleave the water as she passes through it. Not so the steamer; the steam engines make it independent of the winds, and its contained motive power can propel it, if not entirely, at any rate to a large degree, over the water, instead of through it. If sail and steam power are combined, the requirements in the form of the hull will have to be modified accordingly. The proper fundamental condition for steamers is breadth of beam. Broader steamers of the same bulk will steam faster than narrow ones. Broader steamers will be more stable than narrow ones, will have less draught of water for the same dead weight of cargo carried than narrow ones, and consequently they can get into tidal harbors, and estuaries, and rivers where deep-draught vessels cannot go. Breadth of beam has also similar advantages in ships with sail and steam power. But breadth of beam is worse than prohibited by the Board of Trade rules. It is absolutely fined! It is charged for dues by the registered tonnage, for more tons than can actually be stowed. But breadth of beam—at any rate, properly proportionate breadth of beam—is essential to the designer, if he is to give proper outline and form to his vessel. He cannot bring out the best, the easiest, the steadiest, fastest, safest, and most seaworthy and stable form of hull without being as unlimited in the scope of breadth as he is in the scope of length. Neither can he bring out all the good qualities of hull if he be restricted in the application of mechanical principles, or in mode of arrangement. All these are completely independent, except under Board of Trade rules, of the proper requirements for tonnage measurement. All that the Board of Trade ought to do is to ascertain that there is buoyancy enough in the particular ship to be registered for her to carry a given weight of cargo upon a given load-line—in other words, that the cargo-carrying capacity shall be estimated by displacement. Thus, say that a thousand tons of cargo, whether in bulk or dead weight, shall be taken on a thousand tons displacement of water, and that the load-line should be fixed and written on the register at this point. Take it another way: the vessel, when light, draws, say, ten feet of water, it is easy to calculate that with a thousand tons' weight of cargo on board she will draw, say, 20 feet of water. Her load-line should be marked at 20 feet and her registered tonnage certified at 1,000 tons. Do this, and the naval architect can do his very best, and the shipowner will be able to buy a safe ship for almost the price of a dangerous one. He will then pay any small extra cost, as he will save it in insurances at diminished rates, as he can have a vessel which cannot founder, even if cut in two! He will have an easier ship, a faster ship, one that cannot capsize, and he will have no more dues to pay than he ought to do,

and which it is right and proper and honest that he should pay. The accommodation for passengers on this ship will be better than on a narrow one. The stowage of cargo will be better, and the lives of the captain and his crew will be unimperiled by any of the needless and terrible dangers brought about by the senseless rules of the Board of Trade, and its still further objectionable proceedings of allowing the owner to fix his own load-line disc where he pleases upon the ship. The introduction of iron into shipbuilding has been effected by men who were imbued with the notions of wooden sailing-ship builders. Hence the semblance of carpenters' work still remaining in iron ships. The old leaven leavens the mass, sailing ships and steamers alike. The practice of the shipbuilders designing their own ships is a grave barrier to progress in the general improvement of iron vessels. The shipbuilder now generally builds the engines also, and consequently there has arisen the convenient but not incontrovertible theory that the form of the vessel has nothing to do with the speed, and hence we are told that "you can drive any form of vessel at any speed you like, only you must put in the horse-power, and pay for it."

What, then, are the essential requirements for an ideal proper iron ship? (1) Strength, combined with lightness of construction. (2) Safety, by division of the hull by bulkheads, both transverse and longitudinal. (3) Buoyancy sufficient to float the vessel with its cargo properly, and enough to spare as a reserve to prevent the vessel sinking under any amount of damage she may receive afloat. (4) Rigidity in the construction of the hull, so that there shall not be contortions and vibrations of its frames and structure, and that the bearings of the engines and shaft shall not be subject to strains detrimental to the working of the engines. (5) Proper design of ship, so that the vessels shall have the best qualities of easiness, stability, and external form. Seeing the weakness of existing vessels, it is clear that the longitudinal strengthening of the ordinary hull is a most vital matter. Regarding the box girder as the strongest form of iron construction, I have always advocated as the fundamental basis of an iron ship the assumption of this particular rectilineal form. This is easily accomplished, and to any extent required, by the disposion of the transverse bulkheads with an iron deck and the introduction of two longitudinal girders. By rising the kellon internally the box girder chambers, into which the interior of the hull is thus converted, is supported for its whole length, and in this way an end-on-end strength is imparted to the ship as should bear her harmless from serious effects from end-on-end encounters. The longitudinal girders would be of even far more importance against broadside collisions. We have seen the Arona traverse the ocean for hundreds of miles with her bows stove in by collision with an iceberg which would not get out of the way; and we have read of the Vanguard going down in fine weather and in broad daylight from a tap amidships. Amongst merchant vessels, with scarcely any exceptions, iron vessels of all classes go down after broadside collision so suddenly that only a few out of the many on board are saved, even when brave hearts and willing hands are ready to do any deed of daring if but a few minutes of precious time were permitted for the exercise of their courage and their help. By the combination of longitudinal and transverse bulkheads, only one or two local compartments, external to the main and vital interior box girder chamber of the ship, would be filled with water in the most severe collisions, and the sinking of vessels from broadside collisions would be thus eliminated from the category of the serious dangers of the sea. The introduction of longitudinal girders would prevent any dangerous shifting of cargoes, and would also—under a proper Board of Trade system of registration for dead weight of cargo to be carried—a sufficient reserve amount of buoyancy, reserved, too, in the right places, as should, under every circumstance, preserve the vessel from sinking. Such spaces of reserved buoyancy should not be legally used for cargo. They would not remove or take away from the buoyancy ordinarily in action for the flotation of the ship and its cargo, but they would come into action when, and only when, the ordinary buoyancy was interfered with, whether by intake of water by breach of the skin of the ship, or by

the heeling over of the vessel from sail power, or from any other cause. Then the reserved spaces would exert a righting influence automatically, and in direct proportion to requirement. Some of the practical officers of the Board of Trade have personally recognized the value of this system of designs which I have unofficially submitted to them, as also have various officers of the great insurance companies. Some of the most eminent of our best shipbuilders have also been willing to contract for building such vessels as against estimated price, and to take the risk upon themselves of repayment of cost as against very high speed to be realized. But how could the invention progress when the shipowner was subject to loss under the Board of Trade rules for every improvement which he was asked to make, and which, it is true, added something to the cost of the construction of the ship. Even the total extra cost was in some measure due to the unalterable requirements of the Board of Trade, which prevented their surveyors from passing vessels for classification with an external skin of less than a certain thickness, and which thickness might be right in regard to single-skin ships of ordinary construction, where the main strength of the ship is in the skin; but which rules are clearly inapplicable to vessels constructed with an internal box girder chamber, constituting an independent citadel of strength and safety, not to be compromised by the damage or even total loss of the outworks. The Board of Trade have already, on the application of Messrs. Denny, of Dumbarton, eliminated the double bottom from measurement for the registered tonnage; why not go the whole length further and eliminate buoyancy spaces?

Whilst vessels are measured from outside to outside, and the whole cubic contents calculated by the existing rules of the Board of Trade, so long will the rectangular midship section of hull be adopted by shipowners. But it is, as has been said, an unstable form, and water ballast is required to keep the vessel from turning over. The more dead weight cargo that is put in, the better for the stability; but it is the reverse with homogeneous or bulky cargoes, such as grain, cotton, and so forth. If, after the cargo is taken in, the load-line of the ship is brought out of the water by pumping out the water ballast, the instability of the ship is increased. If double sides be permitted to be exempt from tonnage measurement, their adoption by shipowners will be advantageous to them. If the concession of eliminating the double bottoms was right—and it *was* right—then the first concession should be followed and longitudinal side spaces should be conceded also. By taking the actual load-line of a vessel as representing the displacement of water by actual weight of cargo, no vessel with an improper cargo on board could go to sea unobserved, and the pranks which are played with the Plimsoil load-line at this time would be no longer practicable. The dodges played by shipowners between double bottoms and water ballast and cargoes only require to be made intelligible for the public to understand how valueless, in regard to the safety of our sailors, as well as our ships, have been the ways and doings of our Board of Trade, how utterly inadequate has been the legislation on the subject, and how profoundly ignored by Parliament have been the fundamental scientific principles which govern the vital subjects of naval architecture, shipbuilding, speed, safety, and loading. One of the missions of the Inventors' Institute, it seems to me, should be to watch over discussions of such national importance, and in such cases to bring under the attention of the public and of the legislature the scientific principles involved, and to demonstrate the general practical bearings of existing inventions.

At a recent meeting of the Philadelphia Engineers' Club, President Ludlow described tests of the crushing strength of ice, which were made by him in order to learn approximately the strength required for an ice harbor of iron screw-piles, in mid-channel, at the head of Delaware Bay. Eighteen pieces were tried with Government testing machines at Frankford, Philadelphia, and at Fort Tompkins, Staten Island. The specimens were carefully prepared 6in. and 12in. cubes, and roughly cut slabs about 3in. thick, of different qualities and from different localities. For pure Kennebec ice, the lowest strength obtained was 327 lbs., and the highest 1,000 lbs. per square inch. For inferior qualities, the strengths varied from 235 lbs. to 917 lbs. The higher results were obtained, generally when the air temperature in the testing room was from 29 deg. to 36 deg. Fah., as against from 55 deg. to 68 deg. Fah. for the lower results. The pieces generally compressed from ½in. to 1in. before crushing.

EXPERIMENTS ON THE PASSAGE OF ELECTRICITY THROUGH GASES—SKETCH OF A THEORY.*

By ARTHUR SCHUSTER, Ph.D., F.R.S.

From "Nature."

The passage of electricity through gases has of late years become a very favorite subject for experimental investigation. A large number of facts have thus been accumulated, and it becomes of importance to see whether these facts throw any light on the theoretical notions which we have based on other branches of electrical inquiry.

If we have two bodies at a different electrical potential separated by a layer of air, we might imagine the air in contact with the bodies to become electrified, then move on, impelled by the electric forces, and re-establish equilibrium by giving up their charges. The passage of electricity through gases would then be similar to the diffusion of heat. But, however natural such a view would be, it is impossible to maintain it in the face of experimental facts. The experiments which I shall bring before you to-day seem to me to support, on the contrary, the idea that the passage of electricity through a gas resembles the phenomenon studied by Helmholtz under the name of electrolytic convection.

I shall avoid as much as possible all suppositions and hypotheses which cannot be put to the test of experiment; but it seems necessary to start with some assumption in order to avoid too great a vagueness in the subsequent explanations. The assumption which I shall make is this: In a gas the passage of electricity from one molecule to another is always accompanied by an interchange of the atoms composing the molecule. I shall also try to prove that many facts are easily explained by the assumption that the molecules are broken up at the negative pole.

If, in a vacuum-tube of the ordinary form, the discharge is passed at a pressure of about one millimeter, a luminosity is seen round the negative pole which is called the negative glow. A luminous tongue projects from the end of the positive pole, which I shall call the positive part of the discharge, without meaning to imply that it is charged with positive electricity. The positive part of the discharge and the negative glow are separated by a non-luminous space, which I shall call "the dark interval." The glow itself is divided into three layers, the thickness of which increases with decreasing density. Closely surrounding the electrode itself, we have in the first place a luminous layer, which on new electrodes is of a golden color. The spectroscope shows the presence of sodium and hydrogen; the sodium is due to foreign matter deposited on the electrode, and the hydrogen is expelled by the action of the heat out of the electrode by which it had been absorbed. When the electrodes have been in use for some time, the golden color disappears, and the spectrum belonging to the gas used is seen. The second layer is known by the name of the dark space. The third layer is the glow proper.

The theory which I shall endeavor to establish is this: That within the first layer the gaseous molecules are decomposed, that their negative parts are projected with great velocity through the dark space, that this velocity is gradually reduced by impacts within the glow, and that in the positive part of discharge the discharge takes place by diffusion except when stratifications appear.

According to the kinetic theory of gases, the molecule of mercury vapor consists of a single atom, which is incapable of vibration. Mercury has a very brilliant spectrum, which proves that the theory is incomplete in some important point. It is well known, on the other hand, that the theoretical conclusion receives support from the fact that the vapor-density of mercury vapor is anomalous. If, as is generally supposed, the molecule of the majority of gases contains two atoms, that of mercury can only con-

* Abstract of the Bakerian lecture. Read before the Royal Society.

tain one. If an essential part of the glow discharge is due to the breaking up of the molecules, we might expect mercury vapor to present other and much simpler phenomena than the gases with which we are generally accustomed to work. *This, indeed, is the case; for I find that, if the mercury vapor is sufficiently free from air, the discharge through it shows no negative glow, no dark spaces, and no stratifications.* At the ordinary temperature the spark does not pass through mercury vapor, but if a tube free of air, but containing mercury vapor, is heated, the discharge passes always in a continuous stream of light. It is not always quite symmetrical with respect to the two poles; and a very curious tendency of the spark is noticed, to pass at the negative pole rather from the glass out of which the electrode protrudes than from the metallic electrode itself. A brilliant sodium spectrum then appears at the point from which the spark sets out. Whenever small traces of air remain, stratifications are very apt to appear, as a mixture of air and mercury gives fine stratifications, but I have never noticed them after sufficient removal of the air.

I now pass to the description of an experiment which seems to me to be only capable of explanation by the views brought forward in this paper, and I should like therefore to consider them as crucial experiments, which have to be explained by any true theory of the discharge. As negative electrode, I use an aluminum cylinder of 5.5 cm. internal diameter and 8 cm. long. A long aluminum wire running parallel to the axis of the cylinder at a distance of about an inch formed the positive electrode. On exhaustion, the discharge at first passes as a spark in the ordinary way, but as the pressure decreases the glow gradually surrounds the whole cylinder, *with the exception of a dark strip about* 2 *or* 3 *cm. in width, directly opposite the positive wire.* The positive electrode seems, therefore, to repel the negative glow.

The following seems to me a plausible explanation of the phenomenon which I have just described. The rapid fall of potential which is observed on crossing the negative electrode suggests at once, independently of any theory that we have to deal with, the action of a condenser, for we know that no statical charge can produce a finite difference of potential at the electrode, while a double layer will produce a discontinuity. Although it may not be proved that an absolute discontinuity of potential exists at the kathode, it is yet certain that a very rapid fall occurs at that place. This is all that is necessary for the argument.

We recognize such a double layer in the case of electrolytes, but there is an essential difference in the thickness of the layer within which we must imagine that condenser action to take place. In the liquids that thickness must be very small, as is shown by the intensity of the observed polarization currents The positively electrified matter in every case is kept against the negative surface by a joint action of electrical and chemical forces, for it has been shown by Helmholtz that only thus can we explain a difference of potential between two bodies. It is the chemical forces which keep the electricities asunder. The gaseous molecules or atoms, however subject to their mutual encounters, and always having certain velocities, will tend to leave the surface. They are kept near the surface, however, by the electrical forces.

Suppose, now, that a positive electrode is placed near such a condenser. The resistance of the gas is so much greater than that of the metal electrode that we shall assume the whole electrode to be of the same potential. The lines of force will then cut the surface at right angles, and could we assume the condenser to be infinitely thin, there would only be a normal force acting on its particles; but as the lines of force are curved, the particles not in immediate contact with the surface are acted on by a tangential force which will tend to drive them away from the positive electrode. As a steady state will only be possible when the total force is normal throughout the condenser, we arrive at the condition for the steady state that within the condenser the fall of potential must be the same for equal distances measured along the normal to the surface.

Experimental evidence speaks strongly in favor of such a conclusion. If, for instance, a thin wire is used as electrode, it is well known that the tension at the end of the wire before discharge is very much larger than anywhere else. At high pressures the discharge passes indeed

from the end of the wire, but as the exhaustion proceeds, the glow gradually covers the whole wire, and the same amount of electricity flows out of equal areas situated anywhere on the wire, for the dark space which alters its width with the intensity of current is everywhere the same ; this implies that the fall of potential per unit distance is the same all over the wire.

Hitherto we have only assumed a certain number of particles positively electrified in the immediate neighborhood of the negative electrode, and we have left it altogether undecided what these particles are. But if we consider now the fact that the glow does not appear opposite the positive electrode, that is to say, that while the the fall of potential is the same all over the surface the flow is stronger at some places than at others, we are driven to the conclusion that the flow does not altogether depend on the fall of potential, and we must again look for an explanation in the chemical as well as the electric forces. Wherever the fall of potential is chiefly produced by the presence of the positively electrified particle, which I now assume to be the decomposed molecules of the gas, these will help by their chemical action to decompose other molecules. Opposite the positive pole the fall of potential is principally due to nearness of that electrode; chemical forces are absent, and the molecules will not be decomposed. This is, I believe, the explanation of the dark area. And it brings with it the explanation of a large quantity of other facts, as, for instance, the one which has been so long observed and well established, that once a current is set up in the gas it requires a much smaller electromotive force to keep it going. For the discharge, according to us, will generally be introduced by a spark which must give the first supply of decomposed molecules before the continuous glow discharge can establish itself.

I may for the sake of clearness once more mention shortly the principal points of the argument.

The rapid fall of potential in the neighborhood of the negative electrode renders the presence of positively electrified particles in its neighborhood necessary.

If the distance through which the condenser action takes place is sensible, the positively electrified particles will be acted upon by a neighboring positive electrode.

A steady state will be established in which the fall of potential along the normal from the surface will be everywhere the same.

As, however, the flow is stronger away from the positive electrode, we must conclude that other forces besides electrical forces determine the flow.

It is natural to assume that these are chemical forces: that, in other words, the positively electrified particles are the decomposed molecules, which by their presence assist the decomposition of others, and therefore the formation of the current.

Unless a flaw is detected in this line of argument, I think that the conclusion must be granted, namely, that the decomposition of the molecules at the negative electrode is essential to the formation of the glow discharge. This is really all that I endeavor to support in this paper. The rest can only be settled by further experiments. And amongst the rest I count also the primary cause which originally produces the decomposition of molecules at one pole rather than at another. It is possibly due to an electromotive force of contact between the gas and the electrodes which tends to make the gas electro-negative.

The gaseous molecules, then, according to our theory, are decomposed at the negative pole. Their negative constituents can follow the electric action, and as the fall of potential in the immediate neighborhood of the pole is very rapid, the atoms will leave the pole with considerable velocity. That the region of the dark space is filled with matter projected from the negative pole follows almost conclusively from the experiments of Goldstein and Crookes, and is also shown in a most striking way by an experiment due to Hittorf. If a tube contains two parallel wire electrodes at a distance of, say, a quarter of an inch, the discharge will at high pressure pass in the usual way from electrode to electrode, but at very low pressures the discharge from the positive pole goes away from the negative. The results can be shortly expressed by saying that, as far as the positive pole is concerned, the inner boundary of the dark space forms the negative electrode. If the dark space is small and does not

reach to the positive pole, the discharge passes from the latter towards the negative pole, but as soon as the dark space extends beyond the positive pole, the positive part of the discharge goes towards the nearest point of the dark space that is straight away from the negative pole.

We have then two closely adjoining, almost overlapping, parts, in which the discharge is in opposite directions, and this could not be unless electricity is carried by matter which can, owing to its inertia and high velocity, move against the electric forces. To my mind this experiment proves conclusively that the negative electricity is bound to matter projected with high velocity away from the negative pole.

Goldstein has shown when a thin pencil of the negative glow belonging to one electrode passes close to another the pencil is deflected. According to our view, such a pencil would be formed by a succession of negatively charged particles projected in nearly the same direction away from the negative electrode; as these particles pass by another kathode, they are naturally deflected out of their path by the electric forces. Goldstein has shown that if the current is equally divided between the two kathodes, the deflection is independent of the intensity of the current, the pressure, and the nature of the gas. This is exactly what ought to happen according to our theory, for strengthening the current at one kathode means, as will presently appear, increasing the velocity of the particles. The square of the velocity will increase in the same ratio as the total fall of the potential in the neighborhood of the negative pole; as the particles pass the other kathode, the forces from it are increased in the same ratio as the square of the velocity with which they are moving, and consequently the path will remain the same. Similarly all the other experimental facts established by Goldstein can be easily explained.

The most conclusive proof of the view adopted in this paper would be found in the demonstration that the amount of electricity carried by each particle was always the same, whatever the current. I propose to test this fact in the following way:—It was found by Hittorf that the particles proceeding from the negative electrode, and projected at right angles to the lines of force in a magnetic field are bent round in a circle. This is as it should be, and I calculate that the radius of the circle ought to vary as $\sqrt{F/e}$, where F is the total fall of potential within the region in which the particles acquire their velocity, and e is the amount of electricity carried by each particle. As the current increases, it is shown by Hittorf that F increases; and I find that at the same time the diameter of the ring in the magnetic field increases. If this diameter varies as the square root of F, it would be proved that e must be constant as it is in electrolysis. At present we can only say that the average amount of electricity carried by the particles must increase less rapidly than the fall of potential. If e varies at all, we should expect it to vary proportionally to the fall of potential in the neigborhood of the negative electrode, and in that case the diameter of the ring would be independent of the current, which it is not.

The theory which I advocate involves the existence of a polarization, and it might be considered a difficulty that no polarization currents have with certainty been observed in gases. I believe the difficulty only to be apparent, for the experiments prove that the fall of potential near the negative pole, though rapid, is not sudden, so that the layer within which the condenser action takes place is very much thicker in gases than in liquids. The capacity of the condenser is therefore smaller, and though the total fall of potential in the gas may even be stronger than in the liquid, the polarization currents might escape observation.

With regard to the positive part of the discharge it will be sufficient here to mention that stratifications are principally observed in mixtures of gases or in compound gases, and that in the intervals between two stratifications the discharge is very likely carried as through the dark space at the negative electrode, while in the stratifications re-combination of the decomposed atoms takes place.

An interesting law has been proved by Hittorf and E. Wiedemann in the case of the unstratified discharge. Hittorf shows that the fall of potential is the same in the positive part for the same tube whatever the current. This means that the

energy dissipated is proportional to the current, and not to the square of the current as in a liquid. In the latter form the proposition had previously been proved by E. Wiedemann, who has shown that the total quantity of heat generated is proportional to the total quantity of electricity which has passed through the tube, whether in a few strong sparks or many weaker ones.

These experiments seem to point to the fact that once the original velocity of the particles at the regular pole has been reduced the velocity becomes independent of the strength of the current, that is to say, that in the positive part of the current greater intensity only means a greater number of particles taking place in the discharge.

The paper also contains spectroscopic evidence as to the state of dissociation in a vacuum tube, especially in the negative glow.

The question as to how the electricity passes from the electrode to the gas is not discussed, nor is it possible at present to decide, should the theory prove true, whether the polarity of the atoms in the molecule depends on the way in which these are combined, or whether that atom takes positive polarity which happens to be nearest the negative electrode as the molecule approaches it.

In conclusion some novel influence of the magnet on the negative glow is described, and it is shown that two different effects have to be clearly distinguished. The first is an effect of the magnet on the discharge when that discharge is established, and has been sufficiently well investigated. But the second effect depends on the question from what part of the negative electrode the discharge sets out. With respect to this question we meet with many contradictory and inaccurate statements. If at any place the magnet tends to throw the glow together the temperature will be raised, and owing to this fact the current will be strengthened, which again raises the temperature. It may thus happen that a slight cause can induce the current to pass almost exclusively from one part of the negative electrode. For a detailed description the reader is referred to the paper itself and the illustrations accompanying it.

THE TIDAL WAVE AND THE "MASCARET"—IMPROVEMENT OF TIDAL RIVERS.*

By E. SHERMAN GOULD, C. E.

Reviewed for Van Nostrand's Engineering Magazine.

There is perhaps no branch of physical science more interesting than that which relates to the observation of the movements of the ocean and the study of the laws which govern them; and perhaps few departments of applied science call for more genius, or demand higher qualifications than sea-coast and river engineering. There is an awful grandeur belonging to the ocean which rivals in impressiveness the serene stillness of the star-lit heavens, while the triumph of man's intellect in mastering, even if only partially, the laws which the mighty restless mass of waters obeys, seems almost more wonderful than the conquest of the celestial spaces by astronomy. The quiet void of the heavens and the undeviating march of the stars, seem to furnish fit elements for the exercise of an exact science, but how hopeless, one would think, to search for fixed laws in that which is itself the type of instability!

In the volume before us, Mons. Comoy has developed an admirable and comprehensive treatise upon the principal phenomena of wave-motion. Assigning to himself in the first instance the task of studying that curious phase of tidal action known as the *mascaret*, or *bore*, he found himself forced to trace back all the anterior phenomena connected with it, and has so been led to establish the whole theory of wave and tidal motion. This

* *Etude pratique sur les Marées Fluviales, et notamment sur le Mascaret. Par M. Comoy.* Paris, 1881. Octavo, pp. 389. Figures in the text and atlas of 10 plates. Price $5.25.

labor which, in view of the author's main object was but a means to an end, becomes the most valuable feature of the work to the American engineer, because none of our rivers, we believe, present the peculiarity of the mascaret.

Waves may be broadly divided into two classes, namely, Waves of Translation, and Waves of Oscillation.

When a boat with bluff bows is forced along a canal, a certain quantity of water is heaped up under her fore-foot. Should the progress of the boat be suddenly arrested, there would be formed, after a brief period of tumultuous agitation, a wave which would detach itself and roll onward in the direction in which the boat had previously been moving. This wave would be a Wave of Translation. Such waves are formed when a mass of water is shoved forward horizontally by a sufficient force. They move along bodily, extending from side to side of the channel within which they were propagated, widening when the channel widens, the onward motion extending also from the surface to the bottom of the water.

The principal visible characteristic of a wave of translation is that it stands wholly in relief above the adjacent surface, like a hill rising from a level plain.

The velocity with which a wave of translation moves is proportionate to the depth of water in which it is propagated, and its height above the surface. It is represented by the formula

$$V=\sqrt{g\ (H+h)}\mp U$$

in which g=gravity and H and h respectively the depth of water in the channel and the height of the wave, and U the current, if any, in the channel, using the sign + or — according as it runs with or against the direction of the waves.

This velocity V is that of the undulation of the wave: not that of the forward horizontal movement of the molecules of which it is composed. This last velocity, represented by v is given by the proportion:

$$\frac{v}{V}=\frac{h}{H+h}$$

The wave of translation does not reproduce itself: each wave requires a distinct force to generate it. For this reason French physicists give it the name of *onde Solitaire.*

Waves of oscillation are divided into two classes, ordinary and periodic. Of the latter the great example is the tidal wave.

The ordinary wave of oscillation is generated by any force which produces a temporary vertical depression or elevation in the surface of the water. Thus, a stone thrown into the water produces waves of oscillation. They always go in groups, and their principal visible characteristic is a series of alternate elevations and depressions above and below the general surface of the water. The wind, striking the surface of the water obliquely, produces by the action of its vertical component, waves of oscillation.

While the action of waves of translation exercised in the channels of moderate dimensions such as rivers and canals, in which their movements have been studied, extend undiminished from the surface of the water to the bottom, that of the wave of oscillation which has been investigated on a much vaster scale, extends to only a comparatively moderate depth, rapidly decreasing from the surface downward.

This statement must be made, however, under a certain reserve, and must be understood to apply, as regards oscillatory waves, to those of which the length and height are insignificant in comparison with the depth of water in which they are generated. When the dimensions of the waves are great in comparison with the depth of the water, the agitation which they occasion is felt to a greater or less extent through the entire depth.

Periodic waves of oscillation are generated by a series of periodic actions, each one producing a wave; the waves thus produced following each other in regular succession.

It is only the periodic wave of which the movements have been thoroughly investigated.

In deep water, the velocity with which a periodic wave of oscillation is propagated is given by the formula

$$V=\sqrt{\frac{g}{2\ \pi}\ L}$$

In which g=gravity, π=3.1416, and L= length of wave.

If the depth of water be less than the distance below the surface at which the agitation produced by the wave would be manifested if the water were deeper, we

should have, as an approximate formula,

$$V=\sqrt{g\,H}$$

in which H=depth of water.

The above are velocities of propagation, not of translation. It is generally understood that waves of oscillation have no regular horizontal progressive motion, but only an oscillatory movement, as the name implies.

As has been already stated, the tidal wave which twice in each lunar day traverses the ocean spaces of the globe, is the grand representative of the periodic wave of oscillation.

Although this wave is due to the influence of the moon and of the sun, it does not follow the apparent path of these bodies, nor yet coincide with the times of their meridian transits. Thus, the wave coming from the South of Africa, after sweeping around the Cape of Good Hope, rolls to the north towards Europe and bears down upon France and England in a south-easterly direction. Part passes through the channel from west to east, and part goes around the North of Scotland into the North Sea, from north to south. This portion enters the channel from the North Sea, going west, where it meets that portion which, as we have seen, enters the channel from the west.

It would seem that the tidal wave owes its unvarying periodicity to the sun and moon, but once generated by these bodies it is abandoned, as to its future course, to purely terrestrial influences, namely the presence of continents and the greater or less depth of the sea.

The ocean tidal wave is of relatively low height, but immense length and velocity. In seas of great depth, say of 2 miles and over, like the Atlantic, it attains the prodigious length of 5,000 miles. Owing to its great length, we must conclude that it causes motion down to the very bottom of the seas which it traverses.

Owing to the same fact, we have the curious anomaly to encounter, that the wave, in passing over the deepest seas, falls under the classification of an oscillatory wave propagated in shallow water. Its velocity is therefore, as before

$$V=\sqrt{g\,H}$$

Direct observation confirms the correctness of the above formula.

Besides the above velocity of propagation, there are the ebb and flood currents. These currents are more perceptible in proportion as the water becomes shallower.

We may note as one of the remarkable phenomena of the tides, that the turn of the tide does not correspond with high and low water, the ebb commencing before the water has ceased rising, and *vice versa*.

It would be impossible within our limits to even glance at Mons. Comoy's masterly analysis of the various movements of the tidal currents and their causes. Suffice it to say, that he finds them to conform to the *law of least action*, in the exchanges of water necessitated by the undulations of the wave, and that they are exclusively undulatory, having no connection, at least in mid-ocean, with the slope of the surface of the water.

The formula for the mean velocity of the flood-tide is given by the proportion

$$\frac{v}{V}=\frac{h'}{H}$$

In which v=mean velocity of tide; V=velocity of propagation, h' half of the total height of wave, and H=depth of water. By substitution of $V=\sqrt{g\,H}$ as already given, we have

$$v=\frac{h'\sqrt{g}}{\sqrt{H}}$$

for the mean velocity of the flood current.

This formula has been verified by observations in the English channel, near the Pas de Calais.

To calculate the distance traveled by a molecule of water on a flood-tide, Mons. Comoy gives the formula

$$l=\frac{\lambda\,v}{V-v}=\frac{\lambda\,h'}{H-h'}$$

in which l=the distance; v=mean velocity of flood current; V=velocity of propagation of wave; $\lambda=\frac{L}{2}$ half length of wave; h'=half height of wave, and H=depth of water. The length of the wave is given by the formula

$$L=T\sqrt{g\,H}$$

in which T=mean half lunar day in seconds=44,400 seconds.

Mons. Comoy gives some very interest-

ing numerical examples of these formulæ, checked when possible by direct observation, but our limits bar these out, as well as much other interesting matter.

Let us pass to the tides which enter the estuaries of tidal rivers. When the tidal wave of the ocean passes in front of the mouth of an estuary, a *wave of derivation* is detached, which passes up the river. The duration of the tide in the river is the same as that of the ocean tide which caused it, but this is the only point which the two have in common. The tidal wave in the river is essentially a wave of translation, or rather a series of such waves, for Mons. Comoy says:—

"When the sea, lifted by its undulatory movement, begins to exceed in height the level of low water in the river, the water projected into the river produces a first wave which travels up the stream with a velocity proportional to the low-water depth. After this first introduction of the water of the sea, and continually during the whole of the flood tide, the sea, always higher than the water in the river, projects into it new masses of water which give rise to new waves of translation. All of these waves are propagated, like the first, in virtue of the law of their regimen, while new waves are constantly forming at the mouth of the river. At any given moment, therefore, of the flood tide, we find between the embouchure and the first of the flood, a continuous series of waves of translation occupying the entire length of the tide, and forming by their aggregation the forward slope of the tidal-wave of the river, at that moment."

For the velocity of propagation of the crest of the tidal wave in the river, we have

$$V = \sqrt{g\,H} - U$$

the same as for the ocean wave less U, or the down-stream velocity of the river.

As the depth of water in the river diminishes, $\sqrt{g\,H}$ diminishes also. When for any elementary wave it becomes $= U$, that wave ceases to exist.

The distance traveled by a molecule of the water of the flood-tide is given by the formula

$$l = T\,V \frac{v}{V-v}$$

in which l=distance; T=time in seconds of duration of flood; V=mean velocity of propagation of flood-tide during the time T; v=mean velocity of flood current over the distance l.

Observed velocities show that the ratio $\frac{v}{V-v}$ is rarely less than $\frac{1}{3}$, while in some rivers of shallow depth it becomes $\frac{1}{2}$.

This formula has been verified by observing the distance to which the salting of the river water by that of the sea extends in some of the French rivers.

In the chapters devoted to the mascaret, Mons. Comoy goes into great detail respecting the cause and theory of this phenomenon. We will not follow him through this interesting investigation, further than to state the conditions which he finds to exist whenever the mascaret is produced.

The principal condition necessary to the formation of the mascaret, is as follows: during any given period of the flood-tide, a certain quantity of tidal water enters the embouchure, represented by Svt, in which t = any given time, during which the tide at the embouchure rises through the distance C; v=mean velocity of flood-tide at the embouchure, during the time t; S = mean cross-section of the embouchure of river during the time t. This quantity of water after entering the river occupies a volume represented by DLA; in which D=mean distance between the embouchure and the first of the flood: or the distance traveled up the river by the tidal wave, during the time t; L = mean width of river over the distance D; A=mean rise of the tide during the time t, over the distance D.

These two volumes are necessarily equal, for they represent the same quantity of water in two different positions, so we have

$$Svt = DLA.$$

If a mascaret is produced, it will always be found that in the above relation, A > C. C, it will be observed, forms part of S.

In other words, it is found, that when the mascaret is produced, the height to which the tide rises in the river during the time t, is greater than that of the rise of tide at the embouchure, during the same time. Moreover, it is found, that, leaving out exceptional cases, the mascar-

et only exists in rivers of which the shoals are formed inside of the mouth of the river.

In regard to the improvement of tidal rivers, Mons. Comoy confines himself to the consideration of the effects upon the regimen of rivers, by deepening their shallow places, without discussing the means by which such deepening may be effected. He makes the very true remark that the regimen of rivers differs so much in different cases, that we may say with justice that there are as many particular regimens as there are rivers. Some features, however, similar rivers possess, in common, and these are ably studied.

Two very broad classes may be made of tidal rivers; those of which the bar is formed *within* the mouth, and those of which the bar is formed *outside* of the mouth. (In this latter case only, is the shallow portion termed *bar* in English.)

Mons. Comoy states, that in all rivers where the bar is formed outside, or to seaward of the embouchure, there is a marked narrowing of the mouth, the river being much wider for a certain distance above, than it is at the mouth, or embouchure itself. This narrow part is consequently deep, and the bar is formed (*perhaps not exclusively*) by the scourings of the narrow portion, where the velocity is great, being deposited outside the mouth. In rivers where the bar is formed inside the mouth (or where, as we should say, there is no bar) the embouchure is on the contrary wider than the rest of the river. It is in such rivers that the mascaret is most prone to exhibit itself.

In order to obtain actual data regarding the regimen of tidal rivers, the *Administration des Ponts et Chaussées*, authorized observations to be made for Mons. Comoy, of several of the most important tidal rivers of France. These observations were made simultaneously during the spring-tide of Sept. 19th, 1876 and the neap-tide of the 26th of the same month and year. "Instantaneous curves" were thus obtained of great value, which are given in the atlas accompanying the work.

In the foregoing we have done but little more than, as it were, rapidly turn over the leaves of an exceedingly exhaustive and practical treatise upon tides and tidal rivers. Many valuable chapters have been passed over without notice, and over none have we dwelt long. Enough however, it is hoped, has been said to give some slight idea of the character and scope of the volume, and to commend it to the careful study of those scientists and engineers who are interested in the subjects upon which it treats.

TELPHERAGE.*

From "Iron."

The following short summary of the problem of the transmission of power by means of electricity may interest those who have not studied the subject. There are three steps in this transmission—1st, we convert mechanical power into electricity by means of a dynamo; in doing so we incur a loss of from 10 to 20 per cent.; 2d, this electricity, in flowing along a conductor, generates heat, representing a further loss, analogous to that resulting from friction in mechanical gearing. This loss, depending on the distance of transmission, the size of the conductor, and the electromotive force employed, is easily computed. 3d, we re-convert the electricity into mechanical power by means of an inverted dynamo, which we term an electric motor. With motors in which large weights of iron and copper are employed, the loss in re-conversion need not exceed 20 per cent., but with light motors, weighing from 70 lb. to 100 lb., per horse-power, such as we must employ in the locomotives, I could not undertake with certainty at this moment to effect the reconversion without a waste of one-half. The effect of all these sources of loss is, that at the stationary engine I must exert about 3 horse-power for every single horse-power which is employed usefully on the line. I look forward con-

* Abstract of Prof. Fleeming Jenkin's paper before the Society of Arts.

fidently to the time when 2 horse-power at the engine will be sufficient to give 1 horse power to the motor. To put these conclusions in a more scientific form, I may assume the efficiency of my dynamo as 80 per cent., that of my small motor as 50 per cent.* The waste by heat expressed as horse-power is equal to $\frac{C^2R}{746}$ where C is the current in amperes, and R the resistance in ohms. The horse-power represented by the current is equal to $\frac{EC}{746}$ where E is the electromotive force in volts, and C the current in amperes. It follows from the last expression that I may increase the horse-power in three ways, by increasing either E or C, or both. If I increase E, leaving C the same, I do not increase the loss during transmission along the line, no matter what horse-power the given line may transmit. A practical limit is set to the application of this law by the difficulty met with in dealing with electromotive forces above 2,000 volts. Marcel Deprez, taking advantage of this law—first pointed out by Sir William Thomson—has transmitted seven or eight horse-power over seven or eight miles, through an ordinary telegraph wire, and he obtained a useful duty of 63 per cent., taking into account all the three sources of loss which I have enumerated. With small motors I cannot yet promise a result so good as this, and I merely mention it to let you understand that, in speaking of 3 horse-power for one at the locomotive, I am leaving a very ample margin. Quitting generalities, I will give some details as to the electrical and other conditions necessary, in two examples, for what may be considered as typical telpher lines.

First line.—Length, five miles. Length of circuit, out and in, ten miles. Twenty-five trains running at once, spaced one-fifth of a mile apart; speed, four miles per hour. Let each require 1 horse-power on the average; let the motor take on the average two amperes of electric current; let the electromotive force near the stationary engine be 840 volts; the electromotive force at the end of five miles will be about 746 volts.* The total current entering the line will be fifty amperes at the near end of the line. Fifty amperes and 840 volts represent 56.5 horse-power; of this, 6.5 horse-power will be wasted in heating the line; the remaining fifty horse-power will do work in the motors equivalent to 25 horse-power. In order to give this current of fifty amperes with 840 volts the stationary engine will require to exert $\frac{10}{8} \times 56.6$ horse-power, or roughly, 70 indicated horse-power, or somewhat less than three times the useful horse-power. Let us now examine the economical results to be obtained from such a line as this. Mr. Dowson, in an interesting comparison between the cost of horse-power obtained from coal and gas, reckoned the cost per horse-power for a 100 horse-power engine, at the rate of £3 6s. 9d. per annum, to include wages, coal, oil, and depreciation. Mr. Dowson would naturally be led to put the cost of steam power obtained from coal rather high than low. I will, however, adopt a very much higher figure, and assume that the power may cost as much as £6 10s. per horse-power per annum; this gives £455 as the cost of the 70 horse-power required for my telpher line. Let the twenty-five trains each convey a useful load of 15 cwt. In a day of eight hours the line will have conveyed a traffic which we may express as 600 ton-miles, *i. e.*, it will be equivalent to 600 tons conveyed one mile, or 60 tons on each line conveyed from end to end daily. If we count 300 working days in the year, the sum of £455 gives £1 10s. 4d. per diem, and the 600th part of this is about 0.604 of a penny, as the cost of the power required to carry a ton one mile. In Great Britain we ought easily to be able to reduce this below a half-penny per ton per mile, which proves that the apparent great waste, even of two-thirds of the power in transmission, does not involve prohibitory expense. In calculating the whole cost of transport, we must further take into consideration the cost of the installation. Taking the spans at 70 feet, I estimate this cost as follows:

* The last motor tested, weighing 117 lb., made by Mr. Reckenzaun, gave 1.72 horse-power with 54 per cent. efficiency.

* It has been suggested that this fall of potential would be inconvenient for electric lighting, it would be too great; but in Telpherage it would simply cause a small decrease in the speed of the train at the far end, and as all trains would be equally affected, none would overtake the other, and no inconvenience whatever would arise.

Line £500 per mile	£2,500
Engine, boiler, and shed, at £20 per indicated horse-power	1,400
Dynamo and fittings	1,000
Twenty-five trains	2,500
Contingencies	600
Total cost	£8,000

Allowing 12½ per cent. for interest and depreciation, this represents an annual cost of £1,000. Allowing £100 as the salary of an electrician or young engineer, and adding £455, the cost of the power, this gives a total annual expenditure of £1,555 for a daily duty of 600 ton-miles. If we continue to assume the year as containing 300 working days, the total cost of conveying one ton one mile will be found equal to 2.07d. If goods are to be transmitted for long distances, the same calculation applies. We should simply have stations ten miles apart, working lines five miles long on each side of them. This, then, is the practical outcome of the general principles stated at the beginning of this paper. We may expect with great confidence that it will pay investors to convey goods for any distance at the rate of 2d. per ton per mile, by the agency of the suspended telpher line.

Second Line.—Matters are somewhat modified when the traffic is smaller. Making similar calculations for a line one mile long instead of five, with only four trains running at once, we might employ an electromotive force as low as 100 volts; the loss by heating would be insignificant; we should require about 12 horse-power; the work done in eight hours would be 96 ton-miles. I estimate the cost of installation at £1,600, and the annual cost of working £344, without the annual salary of an electrician. This corresponds to 2.875d., or less than 3d. per ton per mile. One very important feature in respect to the cost of telpher lines is the fact that the larger part of that cost is due to plant, such as locomotives, trains and dynamos. This plant can be increased in proportion to the work required; thus there is a very moderate increase of cost in the rate per ton per mile for a small traffic as compared with a large one, and, on the other hand, a line laid down for a small traffic will accommodate a much larger traffic with no fresh outlay on the line itself.

There are numerous minor electrical problems involved, but time does not permit me to enter into the consideration of these to-night. It will be sufficient for electricians when I say that I se mey way to governing, blocking and breaking the trains, without ever interrupting the current used to work the motor, except between the line and rolling wheels. We already know that the interruption at this point, although accompanied by a spark, does no injury whatever. I have often been asked whether the frequent reversals involved in the cross-over system do not tend either to injure the dynamo or the motor. I made special experiments on this very point lately with a compound wound Crompton dynamo and Mr. Reckenzaun's motor with thirty-six coils. I was unable at the commutator of the motor to detect the smallest change in the motion due to the most rapid reversal. At the dynamo commutator I could just see when the reversal occurred, but there was no change of a character to cause the smallest alarm. At the same time I may state that, when from any cause reversals may be thought undesirable, we are in possession of apparatus which we call "step overs," which, without diminishing the simplicity of the permanent way, enable us to send a continuous and unreversed current. These and similar electrical questions, such as the performance of Messrs. Ayrton & Perry's excellent motors, might possibly have had greater interest for electricians than some of the mechanical details discussed to-night; but I have felt that the main point to establish, in bringing this invention before the public, is that we have in telpher lines a means of conveying goods in an economical manner, by lines, locomotives, trucks, dynamos and motors, which have undergone their preliminary trials with success, and can be at once applied to the more searching test of performing work for the public. If I have established this fact, I think you will have no difficulty in believing that the subsidiary electrical problems have been, or will be, readily solved. I hope that at a future period these will be brought before you in detail on many occasions by many men. In conclusion, I will enumerate some of the uses to which telpher lines may be put. They will convey goods, such as grain, coals and all kinds of minerals, gravel, sand, meat, fish,

salt, manure, fruit, vegetables; in fact, all goods which can be divided conveniently into parcels of two or three hundredweight. If it were necessary, I should feel no hesitation in designing lines to carry weights of 5 or 6 cwt. in each truck. The lines will carry even larger weights, when these, like planks or poles, can be carried by suspension from several coupled trucks. The lines admit of steep inclines; they also admit of very sharp curves. Mere way leaves are required for their establishment, since they do not interfere with the agricultural use of the ground. They could be established instead of piers, leading out to sea, where they would load and unload ships. With special designs, they could even take goods from the hold of a ship and deliver them into any floor of a warehouse miles away. When established in countries where no road exists, the line could bring up its own materials, as a railway does. Moreover, wherever these lines are established, they will be so many sources of power, which can be tapped at any point, for the execution of work by the wayside. Circular saws, or agricultural implements, could be driven by wires connected with the line, and this without stopping the traffic on the line itself. In fine, while I do not believe that the suspended telpher lines will ever compete successfully with railways, where the traffic is sufficient to pay a dividend on a large capital, I do believe that telpher lines will find a very extended use as feeders to railways in old countries, and as the cheapest mode of transport in new countries. In presenting this view to you, I rest my argument mainly on the cost of different modes of transport, which may, I believe, be stated approximately as follows: Railway, 1d. per ton per mile; cartage, 1s. per ton per mile; telpher lines 2d. per ton per mile; and let it be remembered that, in taking the cost of cartage at 1s. per mile, the first cost and maintenance of the road is left wholly out of account; whereas in my calculations for the telpher line allowance has been made both for establishment and maintenance.

THE NILE DELTA.

NOTES OF A JOURNEY THROUGH THE N.E. PORTION OF THE DELTA OF THE NILE IN APRIL, '84.

By WILLIAM ANDERSON, M. Inst. C. E.

From Papers of the Institution of Civil Engineers.

Having been commissioned to ascertain why extensive estates belonging to an English Company were wholly unproductive, and indeed incapable of earning the Government land-tax, it is thought that the observations then made may be useful to all interested in the true welfare of Egypt. The district visited was that portion of the Delta lying between Mansoura, a large town on the Damietta Nile, and Lake Burlos, a lagoon connected with the Mediterranean, and thus quite outside the usual track of visitors. The inquiries and investigations were of a definite and practical character, and have produced a profound impression as to the state of the administration, and as to the manner in which the resources of the country are destroyed at their very origin.

The welfare of the agricultural industry, the only source of wealth in Egypt, depends mainly on the efficiency of the irrigation, the drainage, and the means of communication. It soon became apparent, that the estates visited, and many thousands of acres of land around them, were suffering from startling defects in all the three conditions on which prosperity depends.

First, as regards Irrigation. The portion of the Delta inspected, and, indeed, the whole Delta, is intersected by innumerable canals, some used for drainage and some for irrigation. These have been dug at various times, for the most part without reference to any general plan. They are practically devoid of proper locks or sluices for regulating the flow of the water, the method adopted

being to throw banks of earth across the canals, leaving gaps of sufficient width to control the water, these gaps being regulated by stakes, planks, or lumps of mud wrapped in rice straw. Owing to the caprice, corruption or laziness of the officials, the water in the irrigation canals is often too low to command the land, even when the Nile is high enough for the purpose, and at other times the water is allowed to pass so freely as to overflow the banks and submerge large tracts of country. In summer time, between the months of May and of August; during low Nile, many of the canals, for want of proper cleaning and maintaining at the required depth, become quite dry, and thousands of acres of summer crops, such as cotton and rice, perish for want of water. In the district visited, two-thirds of the crop was, last summer, completely lost from this cause. But even when the canals are properly cleaned out, the water is still below the land-level, and every drop required for irrigation has to be raised by imperfect sakiehs, and small steam-pumps. These may be seen dotting the landscape in all directions, and represent an incredible amount of human and animal labor diverted from the more legitimate work of tilling the soil. The cost of this wasteful mode of raising water is at least ten times greater than that for which the same work could be done by large Government pumping stations, or by a better management of arterial canals. This state of things is peculiarly distressing just at this time, when the number of bullocks has been greatly reduced by a formidable epidemic, so much so, that it will be impossible, this season, to cultivate even so much of the land as is capable of being worked.

In the next place, the drainage-canals have been much neglected, especially at their lower ends or outfalls. They all require widening and deepening, so as to carry the drainage waters into the sandy wastes skirting the Mediterranean. The fall of the country is rapid, so that there is no difficulty in securing very efficient drainage. The neglect of the Works Department to attend to this important part of its duties, injures not only the lands depending upon the public canals, but also estates such as the ones visited, which, lying on the edges of the waste, had their own private drainage-canals; for it is in vain that these are kept in proper order, when the water standing on the adjoining lands percolates through the soil, and rises in the better drained portions, bringing up with it the deleterious salts with which the whole subsoil of the Delta is more or less impregnated, so much so, that this salt may be seen lying like snow over vast areas of land. It is absolutely essential to the fertility of the land that the drainage-canals should be constantly kept clear, and that there should be an unfailing supply of irrigation-water all the year round, because it is only by keeping a regular wash of water from the surface downwards that the deleterious salts can be prevented from rising; but when this is done, the fertility of the soil is marvelous, and the richness of the crops is, for the most part, assured. Adjoining one of the estates was a property of 1,400 acres which had been abandoned by its owner for no other reason than that the Government drainage-canal was choked with mud and aquatic plants. The Government had seized the land for taxes; it had twice put up the property for sale without finding a purchaser, and, of course, had lost the revenue from the lands. A single year's taxes would have sufficed to clean out the canal. This is a particular case, respecting which definite information was obtained, but many thousands of acres of other lands were in a similar predicament, as, for example, of the 100,000 acres belonging to the village of Massara, only 12,000 acres are capable of cultivation, on account of the neglect of the drainage and want of irrigation-water.

Lastly, mismanagement has practically destroyed the means of communication. The canals, if properly maintained, would be wide and deep enough to carry cargo-boats as large as those in use in England. These arteries of communication intersect the country in all directions, and yet it costs 26*s.* a ton to bring the produce from the estates visited, a distance of only 33 miles, to the Damietta Nile, and even that can only be achieved during the dry season, because rain makes the towing and bridle-paths impracticable. This state of things could be remedied at a most insignificant cost.

The impediments to cheap communication in a country so highly favored with

what may be termed natural roads are the following:

When the canals are cleaned, the mud is thrown up on to the towing-path, and allowed to harden in the sun, without the least attempt to level it or remove it altogether from the path. The consequence is, that the animals using the bank of the canal tread a bridle-path on a slope. This at all times is difficult foothold, and in wet weather, when the mud gets slippery, becomes dangerous, and even impracticable. Trees are allowed to grow between the towing-paths and the canals, so that in many places towing is impossible, and from the opposite bank trees overhang, so that the towing masts cannot pass. Naturally all these obstructions should be removed. The banks thrown across the canals for the purpose of regulating the flow of water render trans-shipment necessary, and in this way, in the 33 miles of canal specially visited, there were no less than four dams of weirs, necessitating four trans-shipments. The difference of level between the two sides of the dams is never more than a few inches. It would be very easy and inexpensive, in the tenacious soil of the Delta, to construct wooden dams, with lock gates and sluices, which would allow of the barges being locked through, and dues, which would amply cover all expenses, would be cheerfully paid, as they are in other countries. Again, no control is exercised over the cutting of the canal-banks for irrigation or drainage-branches. The people cut through the banks, and neglect to make them good again, thus intersecting the roads with innumerable pitfalls, which render travelling in the daytime fatiguing, and at night impossible. Surely a very moderate amount of supervision would put an end to this nuisance.

Egypt depends for its prosperity on its agricultural produce; but the competition of the whole world, the immensely improved ways of communication in America, in India, in Russia, have had the effect of reducing the price of all the products which Egypt can send into the market, more especially that of cereals, and the price is never likely to rise permanently again. How is it possible that those portions of Egypt which lie at a distance from Alexandria can hope to export their produce when the means of communication are so defective? The inevitable result will be that the country must relapse into a state where just enough is raised to feed a miserable population, and no taxes will be paid, because, there being no sale of produce, there can be no money.

Whatever neglect there may be in the maintenance of the canal-system, there is no slackness in collecting the land-tax, and defalcation is quickly followed by seizure and forced sales, entailing ruin, misery and discontent among the agricultural population.

The conduct of the Administration is inexplicable, because it would entail very little more than the present expenditure to keep the canals in proper order, while it would improve the revenue by making a greater breadth of land cultivatable, and would restore to the land the human and animal labor now lost in raising water in a wasteful manner, and in overcoming the difficulties of transport.

The people do not object to forced labor on their own canals. They have sense enough to know that by no other means can the life-giving streams be maintained, and it is possible so to distribute the work, and so to select the season for doing it, that the task would not press seriously on the people. At any rate, it would be an infinitely smaller infliction than that which now exists as the consequence of neglect and mismanagement, by which the poor struggling peasants see the fruits of their labor disappear year by year, for want of irrigation and of drainage, or, if the harvest be haply secured, rendered valueless by the cost of carriage.

Many distinguished men have, from time to time, been sent to Egypt to set right its finances. Many ingenious schemes have been proposed, but it is doubtful if any who have attempted the regeneration of the finances of the country have turned their attention to the root of the matter. Measures should be adopted to place the cultivatable portion of Egypt in a condition to produce the wealth latent in its lands, in its river, and in its laborious peasantry, and further to provide cheap and expeditious ways of communications, which can alone enable the produce of the lands to be converted into the gold which the financiers thirst for. It would be a

worthy task for England to step in and remove the terrible drawbacks under which the fellaheen suffer. In her Indian engineers and their subordinates she has an admirable and experienced staff of administrators. The same men, the same system, and the same honesty of purpose introduced into Egypt would make a garden of a country which is now almost a wilderness.

A step in the right direction has already been made in the appointment of Colonel Scott Moncrieff, R. E, to the post of Under Secretary of State for Public Works. He has earned a high reputation in India, and will assuredly, if properly supported, do much towards the regeneration of the country entrusted to his care.

Unfortunately, long neglect and mismanagement have rendered large expenditure necessary, while that very neglect and mismanagement have crippled the revenue.

Colonel Moncrieff, has already been ordered to retrench in every possible way, even when it is certain that expenditure such as he contemplates will yield enormous return. He is perfectly alive to the importance of the reforms alluded to. In two "Notes" addressed to the Financial Advisers of the Government, one dated February 13th, 1884, on the communications throughout Egypt, and the other, dated March 4th, on the Public Works which he deems essential to the good administration of the country, he points out in terse and vigorous language the real barriers interposed to prosperity, in the absurd and oppressive taxes on navigation, the impediments offered to it by bridges over the main channels, the defects of drainage and irrigation, and the total absence of roads.

It is satisfactory to be able to state that recently in Egypt one great concession was announced, namely, the river and canals were set free for steam-navigation, a privilege till then reserved to the Government. It cannot be doubted but that this has been one of the results of the improved administration of the Public Works Department, and it is to be hoped that many other reforms will soon follow.

The uncertainty which surrounds the intentions of the British Government is stopping all public and private enterprise, and the poor farming population, that is to say, the bulk of the people of Egypt, is sinking deeper and deeper into a hopeless condition of poverty and debt. This is not a mere statement of opinion; on the contrary, the existing political situation had to be taken into consideration. The canals and drains on the estates visited had long been neglected. An expenditure of £1,500 in cleaning out was absolutely necessary, if advantage was to be derived from the expected improved irrigation and drainage service; and could the company have felt sure of the intentions of the British Government to continue steadily in the course they have entered upon, the work would have been commenced at once. The probabilities are, indeed, in favor of a prolonged occupation, because a great number of British officials have entered the Public Works Department, replacing some able and experienced men, such as Rousseau Pacha and his chief engineer, and it is hardly credible that the British Government would make such appointments if their sway was to be only of a temporary nature. But still the Government assurance is wanting, and it is impossible to advise expenditure of capital which would be fruitless in the event of the withdrawal of the British, for in that case the Government of Egypt would relapse into its original state of inefficiency.

In 1883 the Ministry of Public Works in Shereef Pacha's Government published a most able paper entitled "Exposé du Ministère des Travaux Publics sur les Irrigations d'Egypte, et examen d'une proposition y relative."* It is signed by Ali Pacha Moubarick, then Minister of Public Works, and by Rousseau Pacha, their Director-General. These gentlemen are both men of long experience in the department over which they presided, and Rousseau Pacha, especially, is an engineer of great and varied information. The "Exposé" treats first of the general systems of irrigation and drainage in vogue in Upper and Lower Egypt, discusses the capacity of the Nile at low water, and demonstrates that its volume is barely sufficient for the wants of the existing summer cultivation, and those of navigation. The long-standing question

* An abstract of this will appear in the Minutes of Proceedings, vol. lxxvii.

of the Barrage is carefully considered, and the conclusion is reached, that even supposing by an expenditure of very large sums of money the Barrage could be repaired, or, as they point out, more properly rebuilt, and the banks of the arterial canals raised to a proper height, to convey the waters pent up behind it, Government might well recoil before the enormous risk of so powerfully altering the regimen of a river such as the Nile, and incurring the consequences of injury to a wide extent of productive land brought on by the infiltrations which would be sure to supervene. In addition, they draw attention to the enormous cost of keeping the arterial canals clear, and the absolute necessity of employing for that purpose forced labor in its most odious form, that is, at a distance from the homes of the laborers, and employed on works in which they have no direct interest. The height to which the banks of the arterial canals have risen from centuries of cleaning, renders the labor more and more severe each successive year, and more and more land is being covered by the mud excavated, and by that means rendered valueless. The Rayah of Khatatbeh, in the western margin of the delta, for example, which used to bring the waters of the main Nile from above the Barrage to the Khatatbeh canal, which irrigates the Province of Behera, though only 26 miles long, required annually the labor of 20,000 men for fifty days to clean it. The bare cost of feeding this army used to amount to £12,000, and if to this the labor lost to the farms and valued at only 6d. per head per day be added, there was a further loss to the country of £25,000, making £37,000 per annum for 26 miles of one canal!

In addition, the mud deposited in the arterial canals is the fertilizing essence of the Nile water, and should be deposited on the lands irrigated, and not in the canals. Too much importance cannot be attached to this point. The canals should be as short as possible, and then their currents can be so regulated that the least possible deposit shall take place.

On all these grounds the Exposé strongly advocates the use of powerful steam-pumps, under Government control, in preference to attempting to patch up the Barrage, or make use of long arterial canals. The system would abolish the most oppressive kind of forced labor, would avoid all risk of infiltration, would assure abundant water at all times at a height to command the land irrespective of the level of the Nile, and last, but not least, would save the Government for some years to come, in a great measure, from the very heavy annual outlay in cleaning canals used for the summer water, which now have to be maintained at a great depth, but which, if pumping be resorted to, may be allowed to silt up permanently to a very considerable extent. The Government of Egypt, before the rebellion, had already acted on the principles laid down in the Exposé, and had established a powerful pumping-station at Khatatbeh, and increased the existing one at Atfeh, so as to save the expense and oppression involved in cleaning the Rayah of Khatatbeh. The Government of Shereef Pacha took up the good work, and all but made a contract with an English company to utilize its powerful pumps at Cherbine, which would have supplied the district visited, and invited tenders for the erection and working of another similar station for the Mansourah district. Unfortunately the troubles in the Soudan broke out, Nubar Pacha replaced Shereef, and the arrangements made by the Government of the latter were in a great measure set aside. Colonel Scott Moncrieff (who was appointed about this time) was forced to reduce his budget at the expense of many salutary reforms, and unfortunately with respect to the water supply of the district, which forms the subject of these remarks. At first Colonel Scott Moncrieff seemed favorable to the views advocated in the "Exposé" of the late ministry; but after the Soudan troubles, driven, perhaps, by pecuniary necessity, he unfortunately determined to make an attempt to raise the waters of the Nile by means of the Barrage, and that work is now being strengthened in a manner which he expects will enable it to perform the office for which it was designed. Most experienced engineers, native and foreign, believe that the attempt will end in failure. Mr. B. Baker's graphic description of the work* is of a very discouraging kind, especially as it

* Minutes of Proceedings Inst. C. E., 1879-80, part ii.

is known that when the Barrage was being examined with the view to converting it into a railway bridge, a diver was actually able to make his way right under and across a portion of it! Colonel Moncrieff is very frank about his attempt, and is quite prepared for a failure ; but a failure may prove very disastrous indeed, because, as Rosseau Pacha points out in the Exposé, the Barrage now serves an invaluable purpose in regulating the amount of water passing down the Damietta Nile. Mr. Baker mentions the tendency of the river to follow the shorter, or Rosetta branch, hence, if any serious failure of the Barrage were to occur, the lands depending on the Damietta Nile would suffer severely. Colonël Scott Moncrieff and his assistant have been but a short time in the country ; they have not yet seen the Nile through all its phases. It would surely have been more prudent to postpone the dangerous experiment of dealing with the Barrage to a future time.

Although on the present occasion but a small portion of the country was visited, yet at other times the author has traversed many miles of the canal-system both in Upper and Lower Egypt, and everywhere the same neglect of the vital interests of agriculture exist. Nothing but a strong Government, served by capable and honest officers, will be able to achieve the reforms which will place the irrigation, drainage and communications of Egypt on a par with those of the other civilized countries with which it has to compete. The grand schemes which have from time to time been broached for the construction of regulating reservoirs on the Upper Nile are, as Rousseau Pacha points out, works requiring long years and large sums of money. But the immediate necessities of the cultivatable lands can be satisfied with but moderate outlay, and the returns will be immediate and abundant if the expenditure is controlled by capable and honest administrators ; but the work must be done at once if the revenues of Egypt are to be maintained. The Ministry of Public Works has declared emphatically that "the country cannot wait."

TEMPERATURE OF THE SUN.

By F. GILMAN.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

In the last July number of this Magazine there appeared an article written by Prof. DeVolson Wood, in which he criticised Capt. J. Ericsson's method of determining the sun's temperature ; and made many statements which are undoubtedly erroneous, as we will proceed to show.

He says : "The law that the intensity of heat diminishes as the square of the distance from the radiant increases, is applicable only to the case where the radiant body is considered as a mere point, and even in those cases the law does not give the temperature of the incandescent body. It is evident that Prof. Wood refers to a mathematical point, which has position but not magnitude, and assumes that a material body can occupy such a point, and, to cap the climax, tells us that the temperature of this point, or body, must be infinite! As well might he say that the law that the intensity of gravitation diminishes inversely as the square of the distance is applicable only to a point, or (to speak more rationally) to a material point, or particle of a body. But it has been proved that the same law of gravitation prevails in a spherical homogeneous mass of any dimensions, when the distance is measured from the center ; and it is also applicable in the case of heat radiating from a spherical body, such as the sun ; for gravitation, light, and radiant heat, conform to the same law. Prof. Tait, in his *Treatise on Heat*, declares that this law is necessarily true of any form of energy which spreads rectilinearly in all directions.

Prof. Wood says that the law does not give the temperature of the incandescent body. No, to be sure it does not ; but it gives the temperature of the medium in the vicinity of the body, and the temper-

ature of the body cannot be lower than this, but must be higher, unless the emissive power is equal to unity.

Capt. Ericsson has proved that the temperature of the medium in the vicinity of the sun is at least 1303640° Fahr. The temperature of the sun itself must then be fully equal to this, and is probably much higher. Prof. Wood says: "Experiment shows that the quantity of heat emanated from an incandescent body increases more rapidly than the temperature." This statement is incorrect. The quantity of heat lost by an incandescent body, in a given time, does not depend simply on its temperature, but rather on the difference between its temperature and that of the surrounding medium.

Prof. Wood gives the law deduced by Petit and Dulong in the following equation: $2=1.146 fa^{t}$

We suppose there were some typographical errors in the explanation of symbols that follows, and therefore we will give what appears to have been the writer's meaning, in order, if possible, to get a little sense out of the formula. 2 is the quantity of heat per square centimeter emitted per minute, f the emissive power of the surface, its superior limit being unity; a=1.0077 while t is the temperature in degrees Centigrade of the hot body. It will be noticed that nothing is said about the temperature of the medium in which the body is placed, but let us suppose that it is constantly kept at o° C., as this supposition is the best that can be made consistent with the formula. Even in this case, however, it is seen to be incorrect; for making $t=o$ we have

$$2=1.146 f.$$

That is, according this formula, when the body has cooled down to the temperature of the medium it is still losing heat, which is impossible; therefore the formula is false, or at least incomplete. The following formula given by Piclet in his *Traite de la Chaleur*, p. 373, vol. I., contains the proper expression of Dulong and Petit's law:

$$R=(124.72)\,Ka^{\theta}(a^{t}-1)$$

R represents the quantity of heat emitted by radiation per square meter per hour, K a number which depends on the nature of the surface, a the constant 1.0077, θ the temperature of the medium, t the excess of the temperature of the hot body above that of the medium.

Prof. Wood, who expects such great things from this law of Dulong (which he has incorrectly given), seems to think that it holds true for any excess of temperature, however great; and would even, with Pouillet, apply it to determine the sun's temperature. In reply to this we quote from two authorities to show that Dulong's formula is only empirical, and that it ceases to be true when the excess of temperature is over 200° C.

"*On voit donc d'abord que la formule de Dulong est empirique, puisqu'elle englobe dans une expression commune des elements qui sont differents, et ensuite, qu'elle doit cesser d'être exacte a des temperatures elevees.*"

Jamin's Physique, Vol. ii *p.* 314.

De la Provostaye and Desains have verified the consequences of this formula from o° C., to 200° C., but they state that above the latter temperature it is no longer applicable.

Tait's Heat, p 279.

Hence appears the absurdity of applying such a formula as this to determine the amount of heat radiated (or conversely when the amount radiated is known to find the temperature) from a body like the sun, in which the excess of temperature is so enormous.

The principle which Capt. Ericsson applies, however, to determine the sun's temperature is perfectly general, and holds for any excess of temperature. It is susceptible of mathematical demonstration; and Capt. Ericsson has given in his sun motor an experimental demonstration of it, which is unanswerable.

It seems as if some idea might be obtained in regard to the sun's temperature, by calculating what the temperatures at the earth would be, supposing it to advance by successive stages toward the sun. In order to know how much heat is communicated at present, we must conceive what would be the result if the sun were removed from the universe; or if its heat were entirely extinguished. In that case it is probable that the temperature here would not be far from that of the absolute zero, 460° below zero, Fahr.; and therefore the earth must at present receive from the sun an increment of nearly 400° Fahr. But we will take a much

smaller estimate, and suppose that it is only 100°, and then proceed to calculate what would be the temperature at the earth's surface, were it advanced half-way to the sun's center, or at a distance of 46,000,000 miles. According to the principle above stated, the earth would then receive four times the quantity of heat that it does at present; and assuming (which we may safely do in a question of this kind) that equal increments of heat correspond to equal increments of temperature, the temperature at the earth would be $4 \times 100° = 400°$ reckoned from the absolute zero, or 60° below zero, Fahr., I have assumed an initial temperature far below that known to exist, in order to show to what a high temperature even that hypothesis will lead us, when we reach the sun.

Next, let the earth advance until it is 23,000,000 miles from the sun's center. The temperature will be $4 \times 400° = 1{,}600°$. Continuing this process we shall find that when the earth is 718,750 miles from the sun's center, or 275,750 miles from its surface, the temperature will be 1,798,400° Fahr.

THE STUDY OF IRON AND STEEL.

By J. C. BAYLES, New York City.

Transactions of the American Institute of Mining Engineers.

Gentlemen of the American Institute of Mining Engineers; Ladies and Gentlemen: The propriety of imitating in everything, so far as I am able, the worthy example of the distinguished gentlemen who have dignified the honorable office of President of the American Institute of Mining Engineers, imposes upon me the agreeable duty of delivering an address from the chair. The prominence which has been accorded in the programme of this meeting to the discussion of subjects connected with the study of metals, especially iron and steel, has naturally given direction to my thought.

It seems to be characteristic of invention and investigation that they conform to no law of regular and uniform development. From the measurably firm ground of accepted truth and verified experience, the work of original investigators is projected into the void of the unknown; and so rapid and important are the accretions of fact around such slender spars of well-directed speculation, that it seems for a time as if we might go on extending and building them up until the void was fully and safely bridged. But such a line of investigation is like a cantilever with a pier at one end and nothing at the other. The limitations, not only of knowledge but of speculation, become evident as we load hypotheses upon the unsupported end of our structure; and to make our work of value, we must find a solid basis somewhere else, build thereon a pier, and project therefrom a second cantilever. When these meet and are securely united, we have spanned one of the spaces between facts learned by observation and experience, and can safely pass over to a point from which new speculations and verifications may serve as a basis for further progress.

We are impressed with the appropriateness of this figure when we examine the steps by which we have gained what little knowledge we already possess of the composition and properties of iron and steel. That we know as much as we do concerning them is surprising, when we reflect that among our membership are many whose lives almost include the period in which these materials have been intelligently and systematically studied.

The progress of chemical science applicable to iron and steel analysis, naturally invites attention first. Before quantitative analysis was attempted, certain of the crude reactions of qualitative analysis were recognized. Paracelsus, the marvelous charlatan who lived from 1493 to 1541, knew of some of these; and Boyle, an earnest worker in this field, records several in his "Essay on the Usefulness of Experimental Philosophy," published in 1671. Marggraf, who lived from 1709 to 1783, is the first chemist who is credited with analyses of minerals. Thomson, in his history of chemistry (London, 1831), says

of Marggraf's work: "His attempts were rude, but their importance was soon perceived by other chemists, particularly by Bergman (1735 to 1784) and Scheele (1742 to 1786), whose industry and address brought the art to considerable perfection." Bergman, whose *De Analysi Ferri* was published in 1770, has left a very interesting record of his experimental work, which contributed in a material degree to advance the knowledge of the difference between iron and steel. He employed his pupils to collect specimens of iron from the different Swedish forges, and all of these specimens, to the number of eighty-nine, he subjected to a chemical examination by dissolving them in dilute sulphuric acid. He measured the volume of hydrogen gas which he obtained by dissolving a grain weight of each, and noted also the quantity and nature of the undissolved residue. The general result of the whole investigation was that pure malleable iron yielded most hydrogen gas, steel less, and cast iron least of all. The amount of Bergman's knowledge and the value of his methods may be judged from a table of percentages which he has left us, giving the composition of cast iron, steel and wrought iron. This table shows the following results:

	Cast iron.	Steel.	Wrought iron.
Inflammable air..	40.	48.	50.
Plumbago.......	2.20	0.50	0.12
Manganese.	15.25	15.25	15.25
Siliceous earth...	2.25	0.60	0.175
Iron............	80.30	83.65	84.45

In manganese determinations Bergman evidently took care to avoid the discrepancies which are said to characterize the work of modern chemists, for we find that his manganese percentage is in each case 15.25 per cent. This celebrated chemist confirmed, to his own satisfaction, the conclusions of Réaumur (1683 to 1757), who considered steel an intermediate grade of metal between crude and malleable iron. His experiments showed that malleable iron left the smallest quantity of insoluble residue, steel a greater quantity, and cast iron the greatest of all, and from this he drew his conclusions with respect to the difference between iron, steel and cast iron. "Nothing more was necessary," says Thomson, "than to apply the anti-phlogistic theory to these experiments, as was done some time after by the French chemists, in order to draw important conclusions respecting the nature of these bodies. Iron is a simple body, steel is a compound of iron and carbon, and cast iron of iron and a still greater proportion of carbon. The defective part of the experiments of Bergman, as recorded in this important paper, is his method of determining the manganese in iron. In some specimens he makes manganese to amount to considerably more than one-third part of the whole. Now, we know," continues Thomson, "that a mixture of two parts of iron and one of manganese is brittle and useless. We are therefore sure that no malleable iron whatever can contain any such proportion of manganese. The fact is, that Bergman's method of separating iron ores was defective. What he considered manganese was chiefly, and might be in many cases altogether, oxide of iron. Many years elapsed before a good process for separating iron from manganese was discovered." To this I may add that many more years elapsed before steel containing 30 per cent. of manganese, of which some description will be given in one of the papers to be read at this meeting, became a commercial product.

Among other investigations by Bergman were a series of experiments made by him with a view to ascertaining the cause of brittleness in cold-short iron. He extracted from such iron a white powder, by dissolving it in sulphuric acid. This white powder he succeeded in reducing to a white and brittle metal, by fusing it with a flux and charcoal. Klaproth (1743 to 1817), soon after described this metal as a phosphuret of iron, and Scheele, with his usual sagacity, hit on a method of analyzing it, and thus demonstrating its nature. Meyer seems to have conducted a line of experiments in the same direction about the time of Bergman's work, and he made his conclusions known to chemists in time to dispute with Bergman a claim to priority of discovery. As may be supposed, Bergman's processes were rude and very imperfect. It was Klaproth who first systematized chemical analysis, and brought the art to such a state that the processes could be imitated by others with nearly the same results in each case. Klaproth analyzed about 200 specimens of minerals and metals, and most of his conclusions were so

nearly correct that his successors have, in most cases, confirmed the results he obtained. When he began his researches, chemists were not acquainted with the true composition of a single mineral substance. The service which Klaproth performed for mineralogy in Germany was performed equally well in France by Vauquelin (1763 to 1829). To this chemist we are indebted for a description of the element chromium. All of the early analyses of ores, iron and steel are credited to one or the other of these two chemists. Vauquelin announced that in steel the carbon percentage averaged $\frac{1}{140}$th part. By inclosing diamonds in cavities of soft iron and igniting them, they disappeared, and the inner surface of the cavity was found to be converted into steel. I am not aware that this process is employed at the present time, but judging from the disproportion frequently noted in experimental steel manufacture, between the cost and value of the product, one might suppose it is still in use. Berzelius, in the first quarter of the present century, and Ebelmen, about ten years later, made important contributions to the knowledge of reagents and methods. Berzelius was the successor of Bergman and Scheele. All previous analyses were revised by him, and modern chemistry begins with his era. One of his iron analyses shows iron 90.80, silicium 0.50, magnesium 0.20, manganese, 4.57, carbon, 3.90. The pupils of Berzilius were, to a great extent, instructors of the chemists of to-day.

Karsten, in 1820, recognized the influence of carbon on iron, and stated his belief that iron and steel constitute a continuous series, there being no distinct lines of separation between them. In his judgment it was simply a question of carbon percentage where, in the series, a piece of iron or steel belonged. In his "Metallurgy," published in 1830, he notes the fact that pig iron contains carbon, silicon, sulphur, phosphorus, manganese, calcium, magnesium and chromium. It is probable, however, that all these elements had been previously recognized and described. As early as 1815 there was more or less speculation whether hardness and softness in steel were due to physical or chemical causes. Faraday is credited by Percy with having been, in 1822, the first to point out that a piece of hardened steel dissolved completely in hydrochloric acid, while soft steel always yielded a certain amount of carbonaceous residue when subjected to the action of that solvent. David Mushet, in *Iron and Steel* (1840), gives a very good idea of what was known of metallurgical chemistry at that time. He mentions certain ores which contain "phosphat" of iron, which was generally believed to account for the fact that the iron made from them was cold-short. Mushet, however, was by no means certain of the cause of cold-shortness. Phosphorus, he tells us, had long been regarded as the prime cause of this quality in iron, but by the practical observer this theory could not be considered tenable, for it had always been noticed that the most perfect qualities of iron, notably some of the Swedish makes, gave out in working "a very strong phosphoric smell." Regarding the condition in which carbon exists in iron, Mushet says, "In the works of those who have treated on iron, I have never yet seen carbon which exists in crude iron, distinguished from that absorbed by malleable iron in the process of converting it into steel. I could," he continues, "adduce many facts which to me appear conclusive, to prove that carbon exists in crude iron in a concrete state separable by mechanical division, and that it is united to steel in a gaseous state by the combustion of its base, inseparable in any form by the most minute mechanical reduction." It is surprising to note the earnestness and gravity with which in 1840, these statements were made. It shows the newness of the knowledge which now-a-days serves as the starting-point for discussion on such topics.

Mushet treats very fully of the effect of different substances on the quality of iron. He made a number of experiments by fusing iron with different fluxes in crucibles, and noting the quality of metal produced. One section of his book is devoted to the different proportions of carbon which constitute iron and steel: and he gives the results of fourteen experiments. His method was to fuse a certain number of grains of wrought iron with charcoal in varying proportions and note the increase of weight as showing the amount of carbon taken up. Karsten, however, promptly challenged the accuracy of his methods, and proceeded to

show that Mushet's tables giving the carbon percentages in iron and steel were entirely wrong—much as chemists of the present day are prone to do upon occasion.

It is unnecessary to follow from this point the progress of metallurgical chemistry towards a scientific basis. Its general employment as a means of assisting makers to control the character of their product concerns us more; and this is almost within the memory of even the youngest of our membership. Most of us can recollect when the dependence of the iron-master and the engineer who cared to know the chemical composition of a piece of iron or steel, was upon the general analytical chemist. When the influence of our technical schools began to be felt, and young men well equipped for the work began to displace, in the management of furnaces and mills, those who had gained their knowledge in the school of experience, where the instruction is not always thorough in proportion to the cost of tuition, the laboratory began to be recognized as an essential part of an iron or steel-making plant, and in nearly every establishment with any pretensions to completeness, the chemist has become an important member of the staff. But it is not more than fourteen years ago that this was the exception rather than the rule. Among my letters I have one bearing date of 1872, written by the general manager of an important iron-works. He says: "The president of our company thinks we ought to follow the fashion and have a chemist. To my mind it is a waste of money. When I want an analysis I can have it made—and that is very seldom; for the furnace-manager who needs a chemist to tell him the quality of ore or limestone, or whether his pig iron is soft or hard, had better resign and go to farming. However, if the president says chemist, chemist it is. My object in writing is to know if you can recommend a young man competent to fit up a laboratory and take charge of it. We have very little society here, and it is desirable that he should be a gentleman. My wife plays the piano, and I do a little on the flute, and if we can get a chemist who plays the violin, we could have some music evenings. If you can suggest a man who combines these qualifications I could employ him. I do not know what a chemist would expect, but I should not care to pay more than $10 a week."

When the demand for analytical work in connection with the iron and steel industry began to be felt, it brought into the service of the iron-master a great many clever and ingenious chemists at home and abroad, and a varied and valuable literature of metallurgical chemistry was soon created. The need of accurate analyses was so evident that their importance was, perhaps, somewhat exaggerated and for a time it seemed as if we might safely look to the chemist to answer every question which could be raised by the iron-master or the engineer. Our confidence in tabulated percentages of the component parts of a piece of iron or steel resulted largely from the fact that we knew so little what knowledge was needed for a clear and satisfactory explanation of observed phenomena. From this over-confidence in the power of the chemist to explain everything, there has been a natural, and doubtless wholesome, reaction. Experience has shown that, great as the value of a knowledge of the chemical composition of a piece of metal may be, it is, after all, only a part of the knowledge we need before we can determine with what we are dealing.

To some extent, coincident with this rapid progress of chemical investigation, and within even a shorter period, we have seen the development of the physical test, with the aid of appliances which have attained marvelous perfection in surprisingly few years.

Thomas Tredgold, in his "Strength of Cast Iron," published in 1823, says: "Lord Bacon's idea of a mechanical history, which Diderot attempted to realize, is not so well calculated to fulfill his own views (concerning the advancement of the arts) as a well-directed course of experiments on the nature, forms and properties of materials. . . . . In chemistry much has been done, but an experimental school of mechanical science remains to be formed." Referring to the necessity for more knowledge of physical properties than was at that time possessed, Tredgold says: "The manner in which the resistance of materials has been treated by most of our common mechanical writers has also, in some sense, misled the practical men who are

desirous of proceeding upon sure ground, and has given occasion for the sarcastic remark that the stability of a building is inversely proportional to the science of the builder."

Coulomb, in 1784, made some important experiments on torsion, and was probably among the first to study the effect of continued stress upon the elastic limit of iron and steel. In 1818 Wilson estimated the power required to crush cast iron at 2,240,000 pounds to the cubic inch. Reynolds, quoted by Wilson, recorded an experiment in which a cube of cast iron one-fourth of an inch square, re quired 448,000 pounds to crush it. Tredgold considered it necessary to correct these erroneous estimates, and made numerous experiments with cast iron, testing specimens by static loads and under a drop. The results are given in the work before mentioned. He also made some experiments upon wrought iron, correcting or verifying the results reached with crude methods by various European experimenters between 1758 and 1820. The modulus of elasticity of steel was probably first calculated by Dr. Thomas Young, about 1820, from the vibrations of a tuning fork. The height of a modulus found by this method was 8,830,000 feet, and the weight per square inch was 29,000,000 pounds. That is, a bar of steel 8,830,000 feet in length, and 1 inch square in cross section, would stretch from its own weight to double its original length; and its weight, 29,000,000 pounds, is the modulus of elasticity as ordinarily expressed.

It is within a century that the work of Navier, Perronet, Poleni, Telford, Brunel, and others furnished the basis for a more or less exact knowledge of some of the more easily recognized and described physical properties of iron and steel. Naturally the results reached by these experimenters were as incomplete, and in many instances as mistaken, as their methods and appliances were rude and unsatisfactory. Drop-hammers, single lever testing machines and hydraulic presses were the only power appliances employed in testing during the first half of the present century. Experiments were mostly directed to ascertaining the tensile strength of materials, chiefly iron, steel and wood, under shocks or stresses which, at a single application, would produce rupture. The breaking point thus ascertained was termed the ultimate strength of the material; and, until very recently the data thus gathered were the only bases for calculating the dimensions of members which were expected to resist tension. Resistance to compression was similarly determined by the application of crushing loads to cubes of unit dimensions; and this was deemed satisfactory until the experiments of Hodgkinson demonstrated the previously unrecognized influence upon resistance to compression of the ratio of diameter to length in test specimens.

Among the earlier of the experimenters in this field, Navier is entitled to special prominence. He probably did more than any one else to bring science and practice together, and to make one help the other. Navier's theory of rupture under transverse strain, though since found to be correct only within certain limits, is still quite generally accepted as a basis for calculations dealing with such strains. To Woehler, in 1858, we are indebted for a knowledge of the influence of the repetition of quiescent stresses. This led to the formulation of Woehler's law, that rupture may be caused by the frequent application of stresses, in no instance approximating the original ultimate strength of the metal. The recognition of this law established the significance of the elastic limit in the calculation of dimensions, and marks what is probably the most important epoch in modern methods of dimensioning.

In 1862, Kirkaldy published his "Results of an Experimental Inquiry, etc.," which effected a considerable modification of the views previously held by engineers as to the physical characteristics of materials, especially of steel. These investigations tended in a material degree to popularize experiments with construction materials in the testing machine, and created a demand for such machines, and for accessory apparatus for measuring elongation, etc. The Messrs. Fairbanks were, I believe, the first to produce, in 1863, a testing machine on the multiple-lever principle, and though of limited capacity, this was an important improvement upon previous constructions. They were quickly followed by Riehlé Bros., whose testing ma-

chines still hold a high place in the estimation of experimenters. The next great step forward was marked by the production of Thurston's automatic recording torsional testing machine. The progress continued until it culminated in the Emery testing machine, probably the most remarkable instrument of precision ever built, and the most improved type of which dates no further back than 1880. In the line of automatic recording apparatus the latest form, devised by Abbott, illustrates the high development attained in the construction of testing machine accessories.

The period from 1850 to 1875 was, without doubt, the most fruitful in additions to our knowledge of the physical properties of iron and steel as revealed by the testing machine. It comprised the investigations of Navier, Fairbairn, Woehler, Spangenberg, Kirkaldy and Thurston. The work of these and other investigators, brought the physical laboratory fully abreast with the chemical laboratory, and each has given to work done in the other a value it would not othewise have possessed. But he who should undertake the study of iron and steel with no other light than that which analysis and test can give him, though he would learn much of value, would find himself baffled at every turn by mysteries which these methods of investigation cannot solve. This is especially true of steel. In my experience, very few of those who make or use steel are prepared to accept the statement that chemical analysis alone can be relied upon to determine its quality. It may be broadly stated that certain compositions never make good steel; but the reverse cannot be asserted with equal confidence. With a given composition the result depends primarily upon the perfect admixture of the ingredients. Imperfect melting will give an unsatisfactory product, no matter what the stock used or the composition shown by analysis of the ingot. It will also be questioned by many whether a method of accurately determining the oxide of iron in steel would materially increase the confidence we should feel in a judgment of quality from analysis. It is true that chemical methods are becoming more rapid and accurate every day; but with as complete a knowledge of the stock from which steel is made as chemical analysis can give us, there still remain a great many uncertain factors in the equation of quality. In fact, it seems that the value of ingot analysis may easily be very much exaggerated, and that within certain limits the physical structure of a piece of metal is quite as important to be known as its chemical composition. There are many gentlemen in this audience who could substantiate, by the results of long experience, the broad statement, that without good melting and proper subsequent treatment of the ingot, good steel is impossible with any admixture of ingredients which the chemist may prescribe. Chemistry has its limitations—not quite sharply defined, perhaps, but still evident. If the chemist should ever succeed in giving us a report showing the exact proportion of each constituent of a piece of metal, beyond question or doubt, we might still be in the work before us where the builder is when he stands among his bricks and lumber and the sundry materials he makes use of in construction. If he knew nothing more than the count and tally of his materials he could build nothing.

Nor is the testing machine infallible. What it shows is, to a greater or less extent, dependent upon what the operator seeks to have it show. We all know how, on the one hand, by sudden shock applied to a specimen under stress, it can be made to give results far below any recognized standard; and how, on the other hand, by gentle increments of stress through lengthening intervals of time a piece of metal may be coaxed to show test results far above its real value, and apparently inconsistent with it chemical composition. But even when it is possible to have such confidence in a physical test as can only result from a knowledge that everything connected with it has been honest and fair, and surrounded by safeguards against every known source of error, we must look elsewhere than to the chemist for an explanation of many of the phenomena which the testing machine reveals. If we seek to compare the results of physical and chemical test we shall become hopelessly confused. Generalizations warranted by one relation of composition to qualify will often be contradicted by a different relation, and we should reach the almost despairing conclusion that one or the

other of these methods must be accepted as the sole standard by which to judge quality. Which we should choose would depend upon whether we had formed our opinions in the laboratory or in the mill.

To harmonize what seem to be the often-conflicting results of chemical analysis and physical test, we must seek for a knowledge of causes affecting quality in yet other directions. In this we have already had assistance of the greatest value. The anomalies developed by the steels made by different formulæ, and of samples of a given composition taken at different stages in the process of manufacture, has called attention to the fact that the quality of steel does not alone depend upon what it is made of.

In 1873 the building of three large iron-clads was begun at Brest and L'Orient, and steel was largely used in their construction. Lieut. J. Barba, Chief Naval Constructor at L'Orient, investigated some of these anomalies, and to him we are indebted for the first exact observation of the effect of manipulations upon steel. Barba's work was ably supplemented by that of Joessell, and continued by Pourcel, Holly, Metcalf, Hill, and others, with the result of showing that the influence of manipulation in processes of manufacture is of prime importance in its relation to the quality of the finished product. It is important to know the chemical composition of muck-bar and ingot, but experiment and experience have shown that the beam, the rail, the ship-plate and the bridge-member on which the safety of the whole structure may depend, may be so far below the standard of quality which analysis would lead us to expect, or physical tests of specimens taken at intermediate stages in the process of manufacture warrant us in assuming, that we must seek still further light on the subject in the revelations of microscopic analysis.

In the microscope we have an instrument which promises to supplement the laboratory and the testing machine, to harmonize their seemingly conflicting records, and to detect the influence of shop treatment at every step in the process of manufacture. The work of the microscopists who have thus far turned their attention to iron and steel, has not been complete enough as yet to give us more than a few standards by which to compare our observations, but I do not doubt that within a very few years the microscope will give the laboratory and the testing machine a value for the iron-master, the steelmaker and the engineer incomparably greater than that they now possess. This branch of special investigation is one which offers many attractions for the conscientious student who will approach it in the earnest spirit of scientific inquiry. Within the little circle of the field of a microscope, there is more to be learned of value to science and the arts than the chemist can predict or the physicist explain. It will bring us to the point beyond which no investigation can proceed. Then, as now, we shall realize that "the utmost still is hid;" but when we shall have learned all it is possible to learn from the revelations of the microscope, we shall have followed truth to the limit of human intelligence, and seen it fade into infinite mystery.

Meanwhile, let us remember how new is our knowledge of iron and steel, how incomplete, and how dependent is the student by one method upon the knowledge gained by other methods, some as yet almost untried. It is too soon for broad generalizations. The key to the mystery seems to lie in the structure of the metal, and until we know more of this, and can reason from effect to cause through the known phenomena of analysis and test, we may safely distrust that assurance of conviction and positiveness of utterance which Tyndall tells us are ever characteristic of the "confidence of half knowledge."

The Japanese are seriously considering the utilization of the hot springs near Tokio, as a means of producing heat and power. The subject has been discussed in the Japanese Scismologic Society. In a country where the presence of hot springs and the frequency of earthquakes indicate a rapid increase of subterranean temperature, the thing may be quite practicable. In the "Proceedings" of the Paris Society of Civil Engineers it has even been questioned whether the extraction of the heat would not diminish in some degree the frequency and intensity of earthquakes; but if any considerable heat extraction could be effected, exactly the contrary would be the result.

ON THE REDUCTION OF THE GRADIENT ON CURVES.

By H. P. VINCENT.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

In the following paper are contained the results of an investigation into the nature of the resistance to the movement of trains, arising from curves. The older data, on which it is based, are indeed but "rudely observed facts," as so forcibly pointed out by Mr. Wellington in his celebrated work. There is, however, also a small body of later observations, both published and unpublished, besides my own, of which I have availed myself. Altogether the material is scanty, considering the importance of the subject; and it would therefore be too much to expect a fine degree of accuracy in the resulting formula.

Let Q=number of horse-powers developed by the locomotive in taking a train at uniform speed up any grade—provided that grade be perfectly straight.

P=number of horse-powers developed by the locomotive in taking the same train, at the same uniform speed, up that same grade—provided that grade be all on a curve of the degree d.

d=degree of curve.

n=total number of cars (locomotive and tender included) which constitute the train under consideration.

L=total length of that train.

k=coefficient of curve-resistance; not to be confounded with the coefficient of friction. The coefficient of friction for the different materials have been ascertained under the condition, that the pressure should never become large enough to cause noticeable abrasion. But it is the very nature of curve-resistance to cause abrasion.

Then there is approximately,

$$P=\frac{(1+t^{n+1}-(1+t)}{nt}Q \quad \text{where}$$

$$t=\frac{d\,L}{5730\,n}k$$

This formula is based on the car as a unit. Better results, at least theoretically, may be expected from introducing, as a unit, the axle, or even the rigid wheel-base. Whether the practical benefit will compensate for the increased difficulty of the formula I have not, at present, the means of deciding, but intend to consider at some future day.

To utilize this formula for freight service—the only one I shall here consider—for the purpose of finding the grade g (in per cent.) which, combined with the curve of degree d, shall consume the same power as the tangent grade G (in per cent.), I assume the total resistance of the train on straight and level track, for the usual speed of trains (10 miles per hour) as 8 pounds per ton (@ 2,000 lbs.) of the weight of train. This resistance is greater than the so-called rolling friction of the train. The former is the measure of the work performed by the engine; the latter alone taxes the adhesion. The object here to be obtained is to equalize, not merely the external resistances, but the total work of the engine. This value is but an approximation by Clark's data. There are other formulæ, more complicated, but scarcely more trustworthy. Nothing can give accurate values but an extensive study of indicator diagrams taken under the carefully ascertained conditions of actual traffic.

With this assumption there is

$$g=(G+0.4)\frac{nt}{(1+t)^{n+1}-(1+t)}-0.4 \text{ where}$$

$$t = \frac{d\mathrm{L}}{5730\ n}(0.3 + 0.06d)$$

The value of the coefficient k, as here given, is the weak spot of this formula, for the reasons pointed out in the introduction. Such as it is, it gives fair working results up to 20° or 21° curves. The additional resistance which may be caused by the centrifugal force of the train, is not included. For roads with trains of low average speeds I simply neglect it; and for roads with high average speeds I assume it counterbalanced by the superelevation. In the latter case the use of some kind of transition curve is essential.

L and n depend principally upon the locomotive used; upon the weight of the average car, and upon the weight of its average load. In general, n should be so taken, that the locomotive could just move the train at normal speed from water-station to water-station up the grade under consideration, if it were perfectly straight.

This formula is intended only for the reduction of the grade on curves, which are longer than the train, and for standard gauge roads. For shorter curves a formula might also be given, but it is simpler in practice to use the reduced grade on all curves, long and short alike; but on curves shorter than the length L of train, instead of beginning and ending the reduced grade at the nearest station, resp. half-station to the B. C. and E. C., begin and end it at another station, resp. half-station, further on the curve, in inverse proportion to its length.

As an example, I will take the Mogul locomotives of the Southern Pacific Railroad, of 64,000 lbs., weight on the drivers, total weight with tender, about 120,000 lbs, boiler pressure, 120 lbs. per square inch. It can, with certainty, take 20 average loaded cars up a 1 per cent. straight grade at a speed of twelve miles per hour, at a continuous effect of 412 indicated horsepowers.

The following table shows the grades, which, combined with the curves above them, will require the same continuous effect from the engine, provided that all curves are at least as long as the train. For shorter curves an approximate method has been indicated above; and instead of returning to the full tangent grade for shorter distances than 200 feet, the grade on one curve should gradually pass into that on the other. As a matter of course, abrupt changes of grades are to be eased off by the usual vertical curves.

Degree of curve......	0	1	2	3	4	5	6	7	8
Grade in per cent.....	1.000	0.973	0.935	0.888	0.833	0.771	0.703	0.630	0.553
Difference............		27	38	47	55	62	68	73	77

Degree of curve......	9	10	11	12	13	14	15	16
Grade in per cent.....	0.473	0.393	0.313	0.235	0.160	0.089	0.023	0.037 descend'g
Difference..........	80	80	80	78	75	71	66	60

The third line contains the differences between the grades in thousandths of one per cent. It will be noticed, that these differences are increasing at first, are then stationary and finally are decreasing. This is an expression of the fact, that the value of the coefficient k is but an approximation. It is easy to see, even without graphical representation, that about a $14\frac{1}{2}$° curve on a level would be equivalent to a straight 1 per cent. grade for the locomotive here considered, with such weight of average car and average load, as form the basis of this computation.

Any one objecting, that this table shows too much of a reduction of the gradient, could readily use smaller proportionate amounts, if so inclined. And

even to those, who—rejecting formula altogether—use empirical scales, this and corresponding tables might serve as a kind of preliminary guide. For empirical scales can by much hard work be made, which will give excellent results, as experiments carried out on the more recently built portions of the Southern Pacific Railroad amply prove. The grades on curves on this road are somewhat less reduced than the above table shows, but the whole system was undoubtedly designed originally for a lighter locomotive—probably of the Standard American pattern—than the one there largely used now for heavy freight trains. The methods above advocated, however, are not those of the Southern Pacific. The latter are arithmetically more accurate, but also more laborious.

It has been objected that this investigation rests upon no basis of experimental fact; that the existing state of knowledge does not warrant the use of so complicated a formula; and that it probably contains a theoretical error.

These objections seem to involve an entire misconception of the meaning of a formula, such as the above. This is, like every other physico-mathematical theory, an attempt to combine and harmonize such observations as are available. It is indeed very much to be regretted that the same interest is not manifested in the locomotive that has been lately exhibited in the mechanical movements of the horse, for which the wonderful series of experiments in California form the basis of all accurate knowledge. For then we would now have, or might soon expect to obtain, a large body of scientific experiments on the performance of the locomotive. But as there is no immediate hope of this, the best any one can do is to combine and utilize such observations as there are. An apprehension, that this formula contains a theoretical error, is saying but little against it. I think it very likely that it *does* contain a theoretical error, and would consider it little short of a miracle if it did not. The apparent complication of the formula is nothing against its value, but merely against its convenience. It is in the nature of things that a *simple* formula *cannot* be correct. Besides, the former assumption of a reduction of the gradient in direct proportion to the sharpness of the curve, on all gradients alike does not lead to a *simple* formula for the work performed by the engine, which is after all the fundamental consideration. And less so does the progressive scale given in Mr. Wellington's work. That these scales were never before put into the shape of formulæ does not alter the matter; the mathematical law remains the same, however expressed.

To compare this subject to another of vastly greater importance—the flow of water in channels. For nearly a century a great number of mathematical expressions for the velocity of flow have been given by different investigators. Which of them is the correct one? There is evidently *no* correct one; for every one of them, under certain conditions, gives notoriously erroneous results. And when Messrs. Ganguillet and Kutter published their investigation, was the state of knowledge at the time such as to warrant the use of *that* complicated formula? Nevertheless, very many hydraulicians seem to think that it has helped to advance our knowledge and that it is, in fact, the best in existence.

In view of this and other similar cases, I have no fear of corrupting the scientific conscience of my fellow "railroad-stakers-out" and venture to submit to them my formula with all its imperfections on its head.

A NEW process for working lead fume into litharge and red lead has been described in the "Journal" of the Society of Chemical Industry. The fumes evolved from the working of galena contain lead sulphate, sulphite and oxide, arsenic and antimony, also lead sulphide, and when zinc ores are present, zinc oxide. The lead fume is mixed with sodium carbonate or hydroxide, and roasted. The roasted product is then washed, whereby sodium sulphate and sulphite and sodium compounds, containing arsenic and antimony, are separated. The lead compounds are converted into lead oxide by this treatment. The lead fume may be boiled also with a solution of sodium carbonate or hydroxide, lead carbonate and hydroxide being formed, whilst arsenic and antimony are dissolved. The washed precipitate is then roasted. In the presence of zinc compounds they are removed by boiling with sulphuric acid. If lead sulphide be present, it is necessary to boil first with a solution of calcium hypochlorite. Sodium sulphate is recovered from the liquors after separating arsenic and antimony.

PRIMARY BATTERIES FOR ELECTRIC LIGHTING.

By ISAAC PROBERT.

From the "Journal of the Society of Arts."

It has been said that "history repeats itself," and this quotation was never more appropriate than to the subject that will engage our attention this evening.

All of us probably know that it was by a primary battery that the electric light was first introduced. So far back as 1802, Sir Humphry Davy, using a battery consisting of plates of copper and zinc dipped into dilute acid, obtained the electric arc between poles of carbon. In the *Journal of the Royal Institution* for that year, Davy, in describing some experiments on the spark yielded by the newly-invented galvanic battery, uses these words:—"When, instead of the metals, pieces of well-burned charcoal were employed, the spark was still larger, and of a vivid whiteness." He also pictures an apparatus for, as he says, "taking the galvanic electrical spark in fluids and aeriform substances." It consisted of a glass tube, open at the top, and having a tubular outlet at the side through which a wire tipped with charcoal was introduced, another wire, also tipped with charcoal, being cemented in a vertical position through the bottom.

In the same year, the electric light, sustained by voltaic action, was publicly shown in Paris by the citizen Robertson. Professor Sylvanus P. Thompson, in an interesting communication to *Nature*, has quoted a passage in the *Paris Journal* of March, 1802, from which it appears that the experimenter used a voltaic pile of 120 elements of zinc and silver, to each pole of which he attached a carbon. On bringing the carbons into contact, a brilliant spark was obtained of extreme whiteness.

A few years later, Davy, with the large battery of 2,000 cells, which the munificence of some members of the Royal Institution placed at his disposal, obtained an electric light of a power that has rarely been surpassed, even in our own day.

Thanks to the kind efforts of our Chairman, one of Davy's original battery cells is on the table to-night. The complete battery, to use Davy's own words, consisted "of 200 instruments connected together in regular order, each composed of 10 double plates arranged in cells of porcelain, and containing in each plate 32 square inches. The battery, when the cells were filled with 60 parts of water, mixed with one part of nitric acid, and one part of sulphuric acid, afforded a series of brilliant and impressive effects. When pieces of charcoal about an inch long and one-sixth of an inch in diameter, were brought near each other (within the thirtieth or fortieth part of an inch), a bright spark was produced, and more than half the volume of the charcoal became ignited to whiteness, and by withdrawing the points from each other, a constant discharge took place through the heated air, in a space equal to at least four inches, producing a most brilliant ascending arch of light, broad and conical in form in the middle."

The electrician, Children, constructed a battery of twenty cells having huge double plates four feet by two, of which the whole surfaces were exposed, in a wooden trough, in cells covered with cement, to the action of diluted acids. It was the grandest combination ever then constructed for exhibiting the effects of extensive surface. To quote Davy's words:—"Points of charcoal ignited by it produced a light so vivid, that even the sunshine, compared with it, appeared feeble."

The light obtained by these experimenters was beautiful in the extreme, and naturally excited the admiration and the hopes of the public, or at least of that educated section of the public to whom the advances of science are not unknown; but it was in no way a practical light. The copper-zinc battery used in the experiments was crude, and quite incapable of sustaining a constant current, the carbon points employed for the arc to play between were mere sticks of wood charcoal, which gave an unsteady light and rapidly consumed, and the beautiful regulators with which we are familiar, for

keeping the length of the arc constant, were then quite unknown.

It has just been said that the current obtained by the battery employed in those early experiments was not constant. This want of constancy is due to what is called the polarization of the battery—that is, the deposition of hydrogen gas upon the copper plate. In the working of the battery, the zinc plate is oxidized and transformed into sulphate of zinc by the sulphuric acid in which the plates are immersed. At the same time, hydrogen gas is liberated on the surface of the copper-plate, where it collects and forms a layer of appreciable thickness, which offers considerable resistance to the transmission of the electric current. It also gives rise to an electro-motive force opposed in direction to that of the copper zinc couple. The effect of the polarization of the battery is then to considerably reduce the current flowing, and worse than this, the amount of deposited gas varies with time and other circumstances, and the current likewise varies. Such a battery, when used to produce the electric light, furnishes a light of constantly varying intensity which is extremely painful to use, and possesses other drawbacks also.

It is evident then that a battery, to be of any use for practical electric lighting, must be capable of generating a constant current. It should also possess these other qualifications, viz., a high and constant electromotive force and a small and constant internal resistance. It should consume inexpensive materials, and should consume nothing when it is producing no current. It should be capable of being easily cleaned, and of being supplied with fresh materials. It should require no skilled attendance. Unfortunately, no battery hitherto invented possesses all the required qualifications.

So long as constant batteries were unknown, the electric light remained a scientific curiosity, but the invention, by Grove, in 1836, of his nitric acid battery, gave a fresh impetus to the subject. Of all the points enumerated, the power to furnish a constant current is the most important. As the want of constancy of a battery is due very largely, although not exclusively, to the deposition of hydrogen gas upon the copper plate, inventors naturally turn their attention to the devising of methods of ridding the battery of this objectionable feature. Mr. Alfred Smee was very early in the field; he found that by roughening the copper plate, the disengagement of the bubbles of hydrogen from its surface was greatly facilitated. The gas, instead of forming a smooth layer upon the copper, collected upon the rough portions, and was discharged upwards through the liquid in streams.

On further investigating the subject, Smee found that it was not necessary that these roughenings of the surface should have appreciable size. In fact, better results were obtained with a multitude of small points, from which the gas could be disengaged as quickly as it was liberated by the electrolytic action of the battery, than with a few points of large size, which, although capable of releasing big bubbles, yet permitted the gas to remain on the plate until the big bubbles had been formed by the aggregation of the tiny particles of gas which first appear. He therefore abandoned the copper plate, roughened mechanically, with which his earlier experiments were performed, in favor of a platinum plate, coated with a deposit of very finely divided platinum, obtained by exposing the plate to the action of solution of chloride of the metal, under the influence of the galvanic current. In our own day, platinized silver is often, through a false idea of economy, substituted for the platinized platinum.

This was a very great advance. The Smee battery was justly esteemed at the time for its great constancy as compared with the batteries previously in use. But its constancy, although great in comparison with that of the other batteries then known, was still very far from perfect.

Smee's method of eliminating the ill-effects of the layer of hydrogen was but a method of removal, and the question naturally presented itself to the minds of inventors whether a method of prevention could not be devised. An answer in the affirmative was given by Professor J. F. Daniell, of King's College, who invented a battery which remains to this day unequaled in constancy. You may be interested to hear the description of this first constant battery worthy of the name, in its first form, in the inventor's own words. They are these:

"A cell of this battery consists of a cylinder of copper three and a-half inches in diameter, which experience has proved to afford the most advantageous distance between the generating (that is the zinc) and conducting (that is the copper) surfaces, but which may vary in height according to the power which it is wished to obtain. A membranous tube, formed of the gullet of an ox, is hung in the center by a collar and circular copper plate, resting upon a rim placed near the top of the cylinder, and in this is suspended, by a wooden cross bar, a cylindrical rod of amalgamated zinc, half an inch in diameter. The cell is charged with a mixture of eight parts of water and one of oil of vitriol, which has been saturated with sulphate of copper; and portions of the solid salt are placed upon the upper copper plate, which is perforated like a colander, for the purpose of keeping the solution always in a state of saturation. The internal tube is filled with the same acid mixture without the copper. A tube of porous earthenware may be substituted for the membrane with some little loss of power. A number of such cells admit of being connected together very readily into a compound circuit, and will sustain a perfectly equal and steady current for many hours together, with a power far beyond that which can be produced by any other arrangement of a similar quantity of the same metals.

"The surface of the conducting metal is thus perpetually renewed by the deposition of pure copper, and the counteraction of zinc or any other precipitated metal effectually prevented. The minor affinity of the copper for the acid, however, still remains, and such an opposition could only be effectually avoided by the employment of platinum plates, perpetually renewed by the decomposition in the circuit of chloride of platinum; such an arrangement would be perfect, but too costly for ordinary applications."

This battery, the prototype of all chemical depolarizing batteries, is worthy of attentive study. In it the hydrogen, instead of being deposited upon the copper plate, is oxidized to water by the solution of copper sulphate, and metallic copper in place of hydrogen is thrown down upon the copper plate. Polarization is thus entirely prevented.

If constancy of current were the sole requisite of a battery for electric lighting, the Daniell battery would be admirably suited to the purpose, but it will be remembered that a high electromotive force and a low internal resistance are also essential, and here the Daniell battery fails. The electromotive force of any copper zinc couple is low, and the internal resistance of the Daniell cell is high. The electromotive force might be raised by the device suggested by Daniell of employing platinum in place of copper, and solution of chloride of platinum in place of solution of sulphate of copper, but the expense would militate against the practical success of such an arrangement.

It was reserved for Grove—now the Hon. Sir W. R. Grove, one of her Majesty's Judges, but then Professor of Chemistry at the London Institution—to overcome this difficulty, and to produce a chemical depolarizing battery of high electromotive force, low internal resistance, and employing a comparative cheap depolarizing liquid. Daniell, as we have seen, had appreciated very clearly the advantage of a platinum plate, but his mind seemed so engrossed with his original idea of a metallic solution, as depolarizer, which in decomposition deposit upon the plate dipping into it a layer of the same metal, that the possibility of finding a non-metallic depolarizer does not appear to have suggested itself to him. Grove, however, saw this possibility, and by the substitution of strong nitric acid for the metallic solution, achieved the success which Daniell had vainly sought for. For the first time, the production of the electric light by the acid of a primary battery became possible on a practical scale; and the very year of Grove's invention, the electric light was used for theatrical purposes, at the Opera House, in Paris.

Suggestions by Cooper, Walker, Bunsen, and Archereau, quickly followed, and in the course of a few years the nitric acid battery had assumed its present convenient form.

It would be tedious to tell you of the many attempts to practically introduce the electric light which now rapidly succeeded one another. One of the most noteworthy instances of the employment of this battery is the electric lighting of the Cherbourg Docks, during their construction in 1858, whereby 1,800 men

were enabled to work during the night, when work must otherwise have been suspended.

In 1831, Faraday made the important discovery that when a closed circuit of conducting material—a ring of copper, for example—is moved in the neighborhood of a magnet, so that the conductor passes from a position of one magnetic intensity to a position of a different magnetic intensity, a current of electricity is generated in the conductor, and that when the conductor is moved, so that a current is generated in it, more mechanical work is done in producing the motion than when no current is generated. In effect, this great discovery was that, by the intervention of a magnet and a coil of wire, mechanical energy—the energy of the arm or of the steam-engine—can be transferred into electric energy. Out of this discovery have grown the huge dynamo-electric machines of to-day, which, as generators of electricity for lighting purposes, have almost driven voltaic batteries from the field of competition.

Why is this? Why is it that a dynamo-electric machine should be almost universally preferred to a voltaic battery for the production of the electric light? It is a question of cost—of the relative cost of the two methods of producing an electric current. Let us examine this point a little in detail.

Both in a voltaic battery and in a dynamo-electric machine, the electric energy is ultimately referable to combustion, or, more strictly, to chemical combustion. In each there is a combustible substance, oxygen or an equivalent substance, to sustain the combustion, and the means wherewith to collect and utilize the energy liberated. In a voltaic battery, the combustible substance is usually zinc, and the oxygenous substance sulphuric acid. In a dynamo-electric machine—or rather in the furnace of the engine that drives it—the combustible substance is coal, and the oxygenous substance air. The question, therefore, as ordinarily presented, resolves itself into this: Required a certain quantity of electric energy; can it be more economically produced by burning zinc in sulphuric acid in a voltaic battery, or by burning coal in air in the furnace of the engine of a dynamo-electric machine? In answering this question, we must consider the relative cost of zinc and coal, their thermal equivalents—that is, the amounts of heat obtainable by the combustion of equal weights of the two materials; the efficiency of the battery and the engine and machine—that is, the proportion of useful work obtained to the total energy generated; the cost of the oxidant of the zinc-air—the oxidant of the coal costing nothing; the relative cost, both original and for maintenance of the battery and the dynamo and engine; and the relative cost of attendance. In the case of the battery, there is also the possibility of the utilization of the bye-products to be considered.

To make the matter quite clear, let a practical illustration be taken. Let it be supposed that a house has to be lighted by a hundred incandescent lamps, each requiring a current of .75 of an ampere urged by an electromotive force of 100 volts. The rate at which energy is expended in each lamp, expressed in volt-amperes or watts, of which 746 were equal to a horse-power, will be .75 × 100, that is 75. The energy expended in the 100 lamps will be at the rate of 7,500 watts, which are equal to 10.05 horse-power. But this, it must be remembered, is the actual rate at which energy is expended in the lamps. The energy that has to be developed by the engine is greater, for no dynamo-electric machine is perfectly efficient, no dynamo machine gives out as electrical energy the exact equivalent of the mechanical energy expended upon it. Let it be supposed that the machine used in our installation has a "commercial" efficiency of 80 per cent., that is, that 80 per cent. of the mechanical energy put into the machine reappears in the external or lamp circuit as electrical energy, the balance being wasted in heating the armature coils, and the friction of axles, slipping of belts, and other mechanical sources of loss. Then the rate at which energy is generated by the steam-engine must be 10.05 + 1.25, that is 12.55 horse-power. This mechanical energy is to be produced by the combustion of coal, and if all the heat liberated in the combustion of the coal could be collected and utilized, the supply of coal required to generate energy at the rate of 12.55 horse-power would be very small; but, unfortunately, steam-engines,

even of the best make, have but low efficiency, and a horse-power-hour of energy requires in practice somewhere about $4\frac{1}{2}$ lbs. of coal for its production; 12.55 horse-power-hours will therefore require about $56\frac{1}{2}$ lbs. of coal—say, roughly, half a-hundredweight, the cost of which is not more than 6d. Assuming that the lamps were required to burn for 1,800 hours a year—that is on an average nearly five hours a day—the annual cost for coal would be £45. The prime cost of a suitable dynamo-machine and engine (with boiler) would be, say, £300, the interest on which, at 4 per cent., would be £12, and the annual depreciation, at 10 per cent., £30; the cost of attendance would be about £60, so that the prime cost would be £300, and the total annual cost £147, or £1 9s. 5d. per lamp.

If a galvanic battery is used to supply the current to the lamps, the energy will require to be produced at a rate of somewhere between 10.05 and 20.1 horse-power, for the efficiency of a galvanic battery depends upon the relations subsisting between the resistance of the battery itself and the resistance of the external circuit. When the greater resistance is reduced until it exactly equals the smaller, the greatest possible current is obtained from the battery, but exactly one-half of the energy liberated is wasted in heating the battery. When the external resistance is high, as compared with the internal, the current is less, but the percentage loss of energy is also less. As a matter of practice, therefore, it becomes advisable to arrange the resistances so that the external is greater than the internal, whereby the efficiency of the latter is made to as nearly approach a hundred per cent. as we wish. Let it be supposed that in our installation the efficiency is, as in the dynamo just considered, 80 per cent. To liberate a horse-power-hour of energy, a quantity of zinc must be oxidized equal to 2.022 lbs. divided by the electromotive force of the galvanic couple in use. It is calculable that the highest electromotive force obtainable in any zinc sulphuric acid battery is 2.248 volts, from which, however, a deduction must be made on account of the energy absorbed in the chemical action of depolarization. The amount of the deduction will depend upon the nature of the depolarizer: with nitrate of soda and sulphuric acid it is .708 volt, with bichromate of potash it is .343 volt, and with fuming nitric acid .284 volt. In order to do fullest justice to batteries, let it be assumed that strong nitric acid is the depolarizer used in our installation. The deduction to be made from the total electromotive force of the battery is, therefore, .284 volt, and the net electromotive of the battery is 1.964 volt, which corresponds to a consumption of 1.03 lb. of zinc per horse-power-hour of energy. To liberate 12.55 horse-power-hours, 12.93 lbs.—say 13 lbs.—of zinc must be used. If the price of zinc be taken at $2\frac{1}{2}$d. per lb., the zinc used per hour costs 2s. $8\frac{1}{2}$d. But the expense does not end here. Air, the oxidant of coal, costs nothing; whereas sulphuric acid, the usual oxidant of zinc, is of considerable value, costing, even on the commercial scale, $\frac{3}{4}$d. per lb.

To oxidize a pound of zinc, $1\frac{1}{2}$ lb. of sulphuric acid is required, as is shown by the equation, $Zn + H_2SO_4 = ZnSO_4 + H_2$. To oxidize 13 lbs. of zinc, $19\frac{1}{2}$ lbs. of acid are therefore required, which costs 1s. $2\frac{5}{8}$d.; this, added to the cost of the zinc, makes about 3s. 11d. But we cannot stop even here. In order that the zinc may give the greatest possible return of energy, the electromotive force of the voltaic arrangement must, as has been stated, be high, and this—as a net result, at least—can only be obtained by the aid of a good depolarizing liquid. We assumed ourselves to be using strong nitric acid, and if we suppose that the average effect of nascent hydrogen upon this substance is to produce nitric oxide ($N_2\,O_2$), the amount of acid required will be shown by the equation $2\,HNO_3 + 3H_2$ (equivalent to 3 Zn)$=N_2\,O_2 + 4\,H_2\,O$. It follows, therefore, that the solution of every pound of Zn is accompanied by the deoxidation of $\frac{2}{3}$ lb. of nitric acid. In the production of 12.55 horse-power-hours of energy, $8\frac{2}{3}$ lbs. of nitric acid will therefore be deoxidized, the cost of which, at 6d. per lb., is 4s 4d. This, added to the cost of zinc and sulphuric acid, gives 8s. 3d. as the total cost of materials.

But we have not yet done. A battery cannot be charged, and then kept in action until every grain of zinc and every drop of acid have been consumed. It has been found by experience that no more than about 20 per cent. of the acid can

be utilized. When this proportion has been used, the battery begins to flag, and is soon of no further use for electric lighting until the solution has been changed. The greater part of the acid is thus removed as spent solution. But neglecting this source of waste for the moment, and assuming that by a careful process of "refreshing" it is possible to completely exhaust the acid solution, let us see what the cost of our 10.05 horse-power is when generated by a galvanic battery. We have seen that the cost of materials per hour is 8s. 3d., and assuming, as before, that the light will be required for 1,800 hours a year, the annual cost for materials only is £742 10s. 0d. The prime cost of the battery may be taken at £120, the interest, at 4 per cent., on which is, say, £5, and the annual depreciation, at 10 per cent., is £12. The cost of attendance is very difficult to determine. Primary batteries have as yet been used for electric lighting to such a small extent, that there are, practically, no records of experience whereon to base an opinion. It is claimed by the inventors of batteries that the cost is very small; they say that no skilled attendance is required, and this seems reasonable; and that there is nothing further to do than might be done by a domestic servant in the ordinary course of his duties. Let us assume that this is so, and that the cost of attendance is so small as to be negligible.

If we divide the total annual cost (that is £759 10s.) by the number of lamps, the annual cost per lamp is found to be £7 11s. 8d., as against £1 9s. 5d., when a dynamo machine is used. The difference is great, but it becomes even greater when we remember that it is never possible to completely use the acid solution.

From what has been said, it will be gathered that, in a comparatively large installation such as has been sketched, primary batteries have little chance of success; but for smaller installations, of, say, ten to twenty lamps, there may, perhaps, be a field of action open to them. Few people occupying a house requiring so few lamps as this would incur the trouble of a dynamo and engine, although for health's sake they might not object to the cost of the light as produced by a battery.

In what way is it possible to reduce the cost of electric lighting by galvanic batteries? It is evident that there are four ways open; and invention has been active in all. In the first place, a cheaper oxidizable substance than zinc may be employed; and in the second, possibly a cheaper oxidant than sulphuric acid. Next, contrivances may be adopted by which the solutions are more completely exhausted; and lastly, the bye-products—the substances formed during the action of battery—may be utilized in the arts.

In the first place, as to the oxidizable substance:—Zinc is almost universally employed, but lead and iron have been suggested, and a battery using the latter substance is now before the public.

Next, as to the oxidant, or, speaking more generally, the solvent of the positive element of the cell:—Sulpuric acid has been replaced, among other substances, by hydrochloric acid, and the battery employing this liquid has been introduced by Mr. Ross.

As to the bye-products, little can be said, except that the less said the better. Some promoters of patent batteries make a great point of the value of the bye-products of their batteries, but, as a matter of fact, their statements on this point will seldom bear investigation. A zinc residue contains a certain percentage of the metal in a state of chemical combination, from which it has to be recovered by a somewhat costly process, and one hardly likely to afford any profit to the person using the battery.

It may be interesting to notice that, in the Telegraph Department of the Post-office, no residues are thought worth preserving except the "black mud" (technically so-called) from the Daniell's, which contains a very large percentage of pure copper in the metallic state. Last year there were 69,323 Daniell cells in use, and the sum realized by the sale of the year's "black mud" was £167 14s., or rather more than a halfpenny per cell per year. An idea may be formed from these figures of the magnitude of the sum likely to result from the sale of the zinc residues—which in the Post-office are thrown away as worthless—in the case of an ordinary householder using some ten or twenty cells.

During the past few years, several bat-

teries especially designed for use in electric lighting have been devised; and the inventors of the more important have been good enough to bring their batteries here to-night, or to furnish descriptions of them. These batteries may be divided into two classes; those in which the liquids are kept in motion, and those in which they are allowed to remain in a state of quiescence. Of the latter, one of the most important is that devised by Messrs. Holmes and Burke. A description which these gentlemen have been good enough to furnish reads thus:—

"Each battery of eight cells can be charged or discharged at two operations, by means of a system of siphons formed partly in the substance of the outside cells. In order to charge the battery it is only necessary to fill a wooden measuring vessel with the exact quantity of fluid necessary to run into the battery, to connect this vessel with the long leg of one of the siphon systems, and to raise the vessel to a certain height, when the liquid immediately distributes itself amongst the cells, and is bound to attain a uniform height in each of them. To discharge the battery, it is only necessary to reverse the process.

"The fumes are collected and suppressed. The porous pots are sealed into wooden covers, which contain passages for the escape of fumes. The passages communicate with one main pipe formed in the substance of the cells, and the fumes can thence be led away to the fume box, where they are either dissolved or chemically absorbed, according to circumstances.

"The connections between the cells are so simple that they never can be coupled up wrongly, and they are placed beyond the reach of injury by acids or fumes. They never require disconnection when the battery is discharged or recharged. They require partial disconnection when the plates have to be amalgamated, but the latter, when once thoroughly amalgamated, hardly ever require re-touching. Plates have been run for two months without re-amalgamation.

"The depolarizing liquid is cheap and easily handled. It is made of nitrate of soda dissolved in solution of sulphuric acid of a particular strength. It depends for its action on the formation by the current of nitric acid in the porous pot. The hydrogen entering decomposes the nitrate of soda by the aid of the acid, forming sulphate of soda and nitric acid. The liquid is of very good conductivity, and as the nitric acid is only formed as it is wanted, the inconvenience of handling this very disagreeable acid is avoided.

"The cost of the liquid is only 5½d. to 6d. a gallon. Each gallon furnishes from 750 to 800 ampere-hours of electricity at an electromotive force of 1.92 volt—*i.e.*, about 1.536 watts, or very nearly two hour horse-power.

"The internal resistance of the battery is very low for a primary cell, and equals .02 ohm. as nearly as possible."

It may be added that, like the generality of electric lighting batteries, the batteries of Messrs. Holmes and Bourke employ carbon and zinc as the elements.

The battery which next claims attention is that of Mr. O. C. D. Ross, of which a model is on the table. The chief point of novelty distinguishing it is the ingenious arrangement for charging and discharging the depolarizing liquid.

The battery itself is enclosed in a box, about 1 ft. square by 7 ft. long, which contains thirteen double cells, the plates in each of which weigh about 10 lbs.; the whole box when charged weighs about 2 cwt. Each cell contains two carbon plates (formed of ½ in. carbon rods placed side by side) which are immersed in dilute hydrochloric acid mixed with one-sixth of its bulk of a mysterious compound, called by Mr. Ross "Eureka," but which might doubtless be replaced, without materially affecting the action or the cost of the battery, by nitric acid. The zinc plates dip into a solution of common salt, the liquids being kept apart by porous partitions. The mechanical arrangement by which the carbon cells are filled and emptied is very simple; a horizontal pipe connected by flexible tubes to the bottom of each inner cell is raised or lowered; one end is attached by a flexible tube to a cask of acid, and the other end is led to a waste tank. When the horizontal pipe is raised, and communication with the waste tank cut off, the acid flows, on turning the tap of the acid cask, into the inner cells. When spent liquid is required to be removed, the horizontal pipe is lowered, and the liquid flows from the cells to the waste tank. The outer cells are filled with solution of

salt, in one operation, by pouring the solution into a groove extending the whole length of the box, and connected by side passages with the cells.

The Ross battery has been examined by Dr. Hopkinson, who reports that:—

"Comparing this battery with others, a great deal may be said in its favor.

"Its constancy with a large current is remarkably good.

"The liquids used in the cells are less expensive than in any battery having any pretence to constancy.

"Mr. Ross's method of drawing off and replenishing the liquid is very convenient."

The electromotive force per cell is stated to be 1.82 volt, and the resistance 0.06 ohm.

Another battery, introduced some time back, is that known as the "Edeo" or "Heap" battery. It is a carbon-zinc couple using bichromate of potash as the depolarizer, and dilute sulphuric acid as the excitant. The cells are lined with lead, and hold each $1\frac{1}{2}$ gallons of the bichromate mixture (which can be purchased ready prepared at 1s. per gallon). The zinc plates are 10×6 inches, and so offer a total surface of 120 square inches to the action of the acid; they weigh 3 lbs. each. The electromotive force is stated to be 2 volts per cell, and the resistance 0.2 ohm. The point of novelty is claimed to lie in the preparation of the bichromatic solution, the description of which is best given in the manufacturers' own words. They are as follows:—

"In each lead cell pour six pints of water, and in each repeat the following operation:

"Fill the colander (which is supplied with the battery), with bichromate of potash, and hang it in the cell so that the crystals are just immersed in the water. Pour about one-fourth of three pounds of sulphuric acid over the crystals in the colander slowly, stopping occasionally when the liquid boils. As fast as the bichromate of potash gets dissolved, add more, and continue pouring in sulphuric acid as before, until there are used up for each cell all of one and a-half pounds of bichromate of potash, and three pounds of sulphuric acid. When the liquid is entirely cool, it is ready for use. . . . This fluid will last twice as long as the . . . fluid ordinarily supplied."

Mr. Heap is good enough to exhibit a three-cell battery in action to-night.

In the other or circulating class of batteries there is one deserving of notice. It is the invention of Messrs. Oliphant, Burr, and Gowan. It is a two-fluid bichromate battery, having zincs coated with an extremely thin film of gold before amalgamation. The exciting liquid is a solution of salts of mercury. The liquids for the outer jars and inner porous pots are pumped out of separate tanks into distinct pipes communicating with the first jar and the first porous pot. They then rise up siphon pipes into the adjoining cell, and flow onwards in this way through the whole series. To avoid any possible stoppage through friction in the pipes, it is advisable to have the first cell half-an-inch higher than the second, and so on. Thus, in a series of six cells, the last cell will be three inches lower than the first. The last jar and porous pot are connected to their respective tanks. The tank holding the bichromate solution is fitted as a cell, and works a Griscom or other motor, which causes two small pumps to keep the liquids in constant circulation. The pumps raise two cubic inches of liquid per stroke, and work at the rate of thirty strokes per minute. The pumps are constantly at work day and night, whether the battery is in use or not.

The effect of gilding the zincs before amalgamation is, it is stated, to materially decrease local action.

Many other batteries might be described, and it may be interesting to note that, during the past three years, about 150 patents for improvements in primary batteries have been applied for in Great Britain alone.

A question which presents itself in connection with the problem of economical lighting by primary batteries is this: Is it not possible to effect economy in the lamps—to so improve the lamps that a given expenditure of energy on the part of the battery will develop more light in the lamps than is now obtained? Yes; it is possible. It would be troubling you too much to enter here into a lengthy account of the scientific principles which should guide the designer of the luminous conductors of incandescent lamps. It

must suffice to say, that the ideally perfect conductor would assume a spherical form; its mass would be very small, and its surface also, and the material of which it was composed would possess the power, possessed unfortunately by no known substance, of enduring without change for an unlimited time the passage of a very powerful electric current. Of all substances hitherto used for incandescing conductors, carbon obtained by the intense heating of a pure hydro-carbon is the best. It will give a greater returning light for a given expenditure of energy, and will withstand the action of the conductor longer than any other substance. It will become possible, therefore, by its aid to approach more nearly to the ideally perfect form of luminous conductor than we should otherwise be able to. If also we can so fashion the intimate structure of the carbon, that the particles already have that arrangement which they tend to assume under the action of the current, the type of perfection can be approached even more nearly. This has been done. In a patent obtained in November, 1882, by Messrs. Boullon and Soward, in conjunction with myself, a method was described by which luminous conductors can be obtained of pure deposited carbon formed under the influence of the electric current. By suitable means, these conductors can be obtained of any required degree of approximation to the theoretically perfect form. What thickness they will ultimately assume it is impossible yet to say. The shorter and finer they are made, the greater is the economy, but the shorter is their life. The thickness at which the economy in action is just balanced by the increased cost of renewal of lamps is the practical thickness, but this can only be determined by lengthy experiments, which are still in progress.

It may be noted in passing that high resistance luminous conductors—and they can be made without difficulty with a resistance of 1,000 ohms and upwards to the inch—have the great advantage that they work with a small current, although they necessarily require a somewhat high electromotive force. This enables the copper leads to be much thinner, and therefore less expensive, than in the case of a low resistance luminous conductor, worked by a large current, which is an important point worth bearing in mind. Messrs. Woodhouse and Rawson have quite recently introduced a new lamp, which they call their "hair filament lamp." These lamps have an extremely thin, hair-like filament, whence their name. No particulars of the method of manufacturing these filaments have been published, but it appears that, like the filaments of my colleagues and myself, they are made of deposited carbon. The method of their preparation is carefully kept secret, doubtless for fear of piratical imitations which, although generally easily detected, are yet often hard to prove in a court of law. These filaments are stated to be very efficient. It is said that they will furnish a given amount of light with less than half the expenditure of energy necessary to furnish the same amount in an ordinary thick filament. This is doubtless true: the experiments of my colleagues and myself with our own filaments perfectly support this statement, and we have had the opportunity of experimenting with filaments of much greater length, and therefore light-giving power, than Messrs. Woodhouse and Rawson seem to have had, if a conclusion may be formed from the lamps before the public.

The Recent Danish Armor Plate Trials.—Rarely have experimental tests of armor plates been more closely watched, or followed with greater interest, than those which have lately been concluded at Amager, near Copenhagen. The principal reason for the attention thus exhibited will, no doubt, be found in the circumstance that, whereas most naval powers have definitely settled the question as to the system of armor to be adopted, the Danish Admiralty decided not to be governed by foreign official reports, but rather to judge for themselves respecting the merits of the only principles of armor plate manufacture at present in use, viz., the French steel plates and the English compound plates. The question has now been decided in favor of Wilson's compound armor, and the order for the armor plates for the Ivar Hvitfeldt has been placed with Messrs. Cammell & Co., of Sheffield. This solution of the question will not surprise those who have followed the various stages of the trials as reported in these columns. Yet it must be acknowledged that the Danish Naval Commission have had to contend with unusual difficulties in arriving at a conclusion, for it was known from the first that the Amager trials, instituted as they were, on an independent basis, would have important results. It is a source of gratification to us to know that the order has been placed with an English firm.—*Iron.*

THE METROLOGY OF THE GREAT PYRAMID.

"Who is this that *darkeneth counsel* by words *without knowledge?*
Gird now thy loins like a man, for I will demand of thee, and answer thou me.
Where wast THOU when the foundations of the PYRAMID were laid?
Declare if thou hast understanding.
Who hath *laid the measures of its base*, if thou knowest?—Or who hath *lifted the plumb line against it?*
Whereupon are its *socket stones made to sink?*—or who hath laid upon it the *headstone thereof?*"
Paraphrase of Job xxxviii. 4, 6.

By LIEUT. C. A. L. TOTTEN., U. S. Army.

Written for VAN NOSTRAND'S MAGAZINE.

The opponents of the theory, that the Great Pyramid of Gizeh was built as an intentional exponent of cosmic truths, have lately had occasion to hail with a certain degree of satisfaction the advent of a new literary effort to put their case upon a more defensible position. In a reprint from the *School of Mines Quarterly*, entitled, "The Imaginary Metrological System of the Great Pyramid of Gizeh,"* President Barnard, of Columbia College, has renewed the attack upon the Pyramid, somewhat after the manner of Professor Proctor, and somewhat upon a line which he considers new, and hence deems to be a theory of his own. Taking, however, a similar stand to that originally occupied by Prof. Proctor, the greater part of President Barnard's rhetoric is expended in ridicule and denial.

But mere ridicule is a dangerous weapon. While, indeed it is barbed and pointed, its unbalanced shaft is so utterly devoid of fledging that the archer can never be certain what will be the point of fall to its erratic trajectory. The half-made arrow may return upon the very one who gives the wing to its uncertain flight. Nor is mere denial a potent weapon of defence in an argument of such magnitude as the one which now surrounds the subject of the Great Pyramid. Not only is it an unscientific method, for it will not turn a standing beam, but it is beneath the dignity of those who enter into a public debate upon a scientific subject. We broadly claim that the unsupported employment of these two weapons—ridicule and denial—in the discussion of a subject of such magnitude as that which deals with the origin and object of the Great Pyramid, is equivalent to relying upon a pointless stick as a weapon of offence, and upon a paper circus hoop as shield against *riposte.* The argument has long ago been lifted from the dust of such an arena, and demands the skill of trained and well-equipped contestants.

* Reviewed briefly in the August No., p. 174.

That the subject is really one of magnitude, of scientific import, and of vast and growing interest, is borne out sufficiently by the fact, that it has begotten such a controversy as it has, that such a host of opponents are hurrying into print, and that now, not a year passes in which each side of the controversy does not swell its teeming library. It is not a little strange, too, that the mystery of the subject increases under the penmanship of every one who writes a book upon it. Prof. Proctor's hostility to what he opprobriously termed the "Religious Theory," led him to the attack. Convinced at last of the weakness of mere ridicule, and awakened to much of the undoubted scientific teaching of the monument, he was forced to offer some explanation for facts monumentalized therein too boldly to be simply the results of accident and coincidence. Hence he propounded a theory of his own, and named it an "Astrologic Theory." The fact is, one cannot devote himself to this topic without at last being convinced of the certainty of Promethean design in all its lines and proportions. Hence, if unwilling to adopt theories already advanced, or if committed, as President Barnard undoubtedly is, in being also the President of the French Metrical Bureau, to a new-fangled metrology, to which the Pyramid theory is inimical, the only resort for those who come to the topic, and at length become absorbed by it, is to propound a new theory of their own. This,

as just remarked, is exactly the case of President Barnard. Unwilling to accept openly, even the purely scientific theory of the monument—a theory which Petrie himself does not dispute—he states that if the Pyramid is really "a π Pyramid, as it undoubtedly is, it is so *by accident.*" So, too, throughout his discussion of the monument, every cosmic fact or ratio which we meet is declared to be an accident. Nevertheless, waxing warm at length in his subject, even the President of the Metric Bureau cannot resist the tendency to theorize, even if it only be in ridicule, and so he propounds a "Lunar theory connected with the worship of Isis."

Unfortunately for our estimate of President Barnard's information upon pyramid matters, he proposes this theory sarcastically, and in utter ignorance of the fact that the whole ground he endeavors to ridicule has long ago been covered in sober earnest by Joseph Baxendell, F. R. A.. S. Mr. Baxendell, an able astronomer, and a firm believer in the ideas of Prof. Smyth, long ago noticed all of the lunar references of the Great Pyramid alluded to by President Barnard as his own discoveries, and they have been familiar matters for years to all well-informed pyramid students. Indeed President Barnard might have found these lunar relations set forth at length in Mr. Proctor's volume of the Pyramid's solution, a volume which he certainly has no excuse for not having consulted.

The President does not, however, propose his theory in good faith, but in a spirit of sarcasm and innuendo. He puts it forth merely as *moonshine* "for the lunatics," who are bathed in pyramid fantasies, to walk in. He says he does so in the magnanimous hope that in thus ridiculing the whole subject he may at length "induce some of his fellowmen to apply a little common sense to the study of a subject which has been heretofore involved in an elaborate web of ingeniously contrived mysticism."

We do not intend to review this effort of President Barnard at any great length, simply because to answer all of his headings would require a volume much larger than his own. Life itself is far too short to be spent in attempting to set right every pedestrian, who is recklessly astray upon a road where careful surveyors have already erected numberless and sufficient guide posts.

Those familiar with the dignity and scope of this topic cannot but arise from the perusal of President Barnard's paper with a feeling of dissatisfaction that, after all, he has introduced into the "Battle of the Standards" no new forces, and in reality has failed to rally even those already put to flight. The whole argument of *design* based upon the exquisite harmony of the monument, a harmony which pervades and connects each chamber and passage with every other, has no weight whatever with President Barnard. It has either escaped him entirely, or else, having no explanation for coincidence, so consummate as to be mathematically beyond the realm of chance, he has purposely avoided its discussion.

But this harmony is the prime motor of the mental process by which the mind of a candid man is always compelled to recognize design and continuity. Once convinced of the nature of the facts actually built into this monument, one might as well doubt it as an architectural reality, as to question the cosmic intentions of its builder in its due and intimately related proportions. Did the evolution theory of the School of Science, to which President Barnard belongs, rest upon facts as clearly made out as are those built by human hands into this wonderfully proportioned building, there would be no defensible ground for its rejection. But the very scholars who are loath to accept even human intention in the planning of the Gizeh monument, argue devotedly in favor of the evolution theory, based upon premises of the same kind, though infinitely less convincing. Their ways are thus not equal. Even Mr. Petrie and Mr. Proctor are forced to admit that an unique *system* of structure runs throughout this monument, while it is only in a spirit of sarcasm that President Barnard ever does so.

In his discussion of the subject each claim of the believers in cosmic design receives a separate examination, and at the doctor's hands is made to appear somewhat out of gear, or to be slightly at variance with modern scientific estimates of the things monumentalized. It is as if one denied the existence of a chain, or claimed that its continuity was

a matter of mere chance, because its several links were somewhat worn, or bent with age, and with misuse.

To those who may have an opportunity, and who are willing to examine both sides of this matter for themselves, it will be apparent that President Barnard has by no means weakened the chain of evidence in thus pointing out, here and there, a link misshaped. For besides the argument of *continuity*, which he does not at all dispute, nor even allude to, there always remains the fact that modern science itself does not certainly know the exact value of any cosmic truth, by means of which President Barnard can pretend to pronounce unerring judgment upon the absolute accuracy of the Pyramid. Nor will the fair mind, bent upon reaching the *truth* of this monument, ever lose sight of the still more astonishing fact that every new and modern calculation of these cosmic data results in a closer approximation to those actually built 4,000 years ago into the monument.

Throughout his book, President Barnard loses no opportunity of frequently reiterating the statement that these ancient peoples could have had no means of determining these facts by actual calculation. He also denies that they knew or even used them in their daily life. To have possessed them would have made them "modern" in every sense of the word, and to have had them and not have used them is preposterous. This, too, is exactly what the Pyramid students themselves claim. It is their fundamental premise; it is, in fact, the very one of all others upon which the conclusion that the architect wrought wiser than he knew, was inspired—must have been inspired—is firmly founded. For the facts are there, harmoniously disposed, and always occupying middle ground between the extremes of the best modern estimates, and as these estimates converge, upon recalculation they always have the pyramid values round about their mean. Moreover, this pyramid value is always found to be a true "mathematical function," dependent upon the "problem of the three bodies," and resulting from its proper discussion. They were not known as facts of practical value, or of cosmic import to the world in the day which saw the pyramid erected. The very π value is only of modern discovery, and could not have been known to the ancients, yet it is laid out architecturally an hundred times throughout the monument. Was this chance? The modern doctrine of chances replies to us that the odds against a successive coincidence so astounding are in the ratio of one hundred raised to the hundredth power to one. This is unity followed by 102 ciphers, a number past conception, indeed it is a number which is upon the very verge of our utmost powers of enumeration. And yet the π values and harmonies of this monument are few in number compared with the myriad of others linked to them, that reflect and multiply throughout the structure the fundamental facts of every human science known.

Let us examine, for instance, a single one of the links which President Barnard claims is bent, and which he therefore would have us believe is not a link, and hence that the chain of evidence is not a chain at all. We can examine any one of them, but as modern science has perhaps studied the Sun Distance with greater care, and at far greater expense than any other question we will select it.

President Barnard argues upon the Pyramid's reference to this distance, as follows:

"The article of the Pyramid faith which presents itself for examination next in order is the proposition that the height of the Pyramid is exactly one one thousand millionth part of the mean distance of the earth from the sun. Inasmuch as we do not know the exact mean distance of the earth from the sun, it is impossible to subject this statement to the test of a rigorous comparison; but inasmuch as the builders of the Pyramid knew in all probability a great deal less about the matter than we do, it is next to impossible that the proposition should be true. Supposing it, however, for the sake of argument, to *be* true, the fact may be accounted for on either of two hypotheses—it is true accidentally, or it is true intentionally. Against the first of these hypotheses, the probabilities are in the proportion of infinity to zero; and this alternative, moreover, would be rejected with scorn by the disciples of the pyramid religion. But that the fact may be true *in the intention of the builders*, as

asserted, we must assume for them a knowledge which we have no reason to suppose them to have possessed. This slight difficulty the true believers dispose of summarily, by taking it for granted that their human ignorance was illuminated by direct inspiration from on high. The orthodox doctrine on the subject, therefore, is that the true distance of the sun was miraculously made known to the Pyramid architects, and therefore that the height of the structure itself was made, not pretty nearly but, exactly the one-thousand millionth part of that distance.

Now what are the facts on which this extraordinary assertion rests? Simply these: In 1867, Mr. William Petrie, having satisfied himself that the perimeter of the base of the pyramid 'has been *proved* to symbolize a year, or the earth's annual revolution around the sun,' and, further, 'that the radius of that typical circle had also been shown to be the ancient vertical height of the Great Pyramid, the most important and unique line which can be drawn within the whole edifice,' was moved by these weighty considerations to conclude that the same line '*must* represent also *the radius of the earth's mean orbit round the sun:* and in the peoportion of $1:10^9$, : or 1 : 1,000,000,000: because, among other reasons, 10 : 9 is practically the shape of the Great Pyramid. For this building' he proceeds, 'notwithstanding, or rather by virtue of, its angle at the *sides*, has practically and necessarily such another angle at the *corners*, that for every *ten* units its structure advances inward on the diagonal of the base, it practically rises upward, or *points to sunshine* by *nine.* Nine, too, out of the ten characteristic parts (viz., five angles and five sides) being the number of those parts which the sun shines on, in such a shaped pyramid in such a latitude near the equator, out of a high sky.' (*Our inheritance in the Great Pyramid*, Edition of 1874, p. 48.)

This is the logic, and the whole of the logic, on the basis of which a fact is asasserted which, to plain human reason and simple common sense, is so grotesquely improbable, that its possibility can only be defended by clothing it with the character of miracle. The true believers have not failed, accordingly, to be affected by a sort of painful misgiving lest this *a priori* argument should be found unsatisfactory to a skeptical world. They have therefore sought for a confirmation of their hypothesis in comparing the result furnished by it with those deduced from the most recent investigations of the solar parallax.

Since early in this century the mean distance of the sun has been generally taken to be about 95,000,000 miles. This value has been obtained from the parallax as computed by Encke at Altona, in 1822, with data derived from the transit of Venus of 1769; a parallax which he found to be 8″.5776, giving for distance 95,454,000 British statute miles. In 1857, Prof. Airy proposed a new method for determining planetary distances, founded on displacements of Mars in right ascension, as observed morning and evening from a single station, when in opposition at its nearest approach to the earth. This method was applied in 1862, by observations made at Victoria, New South Wales, and by others made at the Royal Observatory, Greenwich, during the opposition of Mars in that year; and the results, as computed at Greenwich, gave a parallax of 8″.932, and a distance of 91,551,000 miles. In the meantime, Leverrier at Paris announced (in 1861) that in order to reconcile discrepancies in the theories of Venus, the earth and Mars, it was necessary to assume a parallax approaching perhaps 8″.95. From this is obtained a solar distance of 91,357,000 miles. Chambers (Astronomy p. 3) assumes as a probable value of the parallax 8″.94, which gives 91,465,000 as the distance. On the other hand, Prof. Newcomb, in his Popular Astronomy says: 'It would appear that the solar parallax must lie between pretty narrow limits, probably between 8″.81 and 8″.86; and that the distance of the sun in miles lies between 92,200,000 and 92,700,000 miles.' Furthermore, Prof. Young in his recent book on the sun, remarks: 'It would seem that the solar parallax cannot differ much from 8″.80, though it may be as much as 0″.02 greater or smaller; this would correspond to a distance of 92,885,000 miles.'

Besides the astronomical methods, of which there are others not here noticed, there is one of great scientific interest dependent on the velocity of light. The time required for a luminous impulse to

reach the earth from the sun is known within about a second or less, so that if we can ascertain how far light travels in a single second, we are possessed of all the data necessary to secure a very close determination of the distance of the sun. Independent methods for the experimental solution of this problem were devised some years ago by Messrs. Fizeau and Foucault, of Paris; and one of the other of these methods has been repeated by M. Cornu in France, and by Lieut. Michelson of the U. S. Navy Academy at Annapolis. The results obtained by the experimenter last named, are regarded as very closely approaching the exact truth. They give 299,900 kilometers as the velocity of light per second; and as light is 498 seconds in coming to us from the sun, we find the solar distance to be 149,350,000 kilometers, equal to 92,803,464, miles. This nearly corresponds to a parallax of 8″.81 which would give a distance of 92,876,000 miles.

Now the distance of the sun as worked out on the Pyramid theory is 91,837,000 miles. This is in the neighborhood of some of the astronomical determinations. It exceeds the lowest of them, and falls short of the highest. Prof. Smyth accordingly jumps, in this case as in many others in which a favorite quantity of his falls somewhere among several of the same class, directly to the conclusion that because his quantity is neither the smallest nor the largest, therefore it is the true one. But if we consider the judgments of astronomers as to these various determinations, we shall see that the inferior ones have no standing with them at all. Newcomb, our highest authority in this country upon physical astronomy, places the probable distance at about 92,500,000 miles, and Young puts it as high as 92,885,000; while the experiments on the velocity of light, which are esteemed to furnish the result most worthy of confidence, give a result almost identical with the estimate of Prof. Young. The Pyramid distance is, therefore, only about a million of miles too short; while, probably, the uncertainty which still attaches to scientific deductions is not so great as half a million.

But there is another consideration which is quite conclusive as to the question now under discussion. The pyramid is said to be, and appears to be really, a π pyramid. But in a π pyramid the height is equal to the perimeter of the base divided by 2π. In such a pyramid, when the base is given, the height is unalterably fixed, and cannot have a value assigned to it at the caprice of the constructor. Now it is a doctrine vital to the pyramid religion that the side of the base shall contain the sacred cubit of the Hebrews as many times exactly as there are days, integral and fractional, in the tropical year. The height must, therefore, be that which this supposition demands, and it can be neither more nor less. On the other hand, if the height had been arbitrarily fixed at one one-thousand millionth part of the earth's mean distance from the sun, the side of the base must have had a value such as *this* hypothesis requires; and could not have been determined by the cubit and the number of days in the year. It exceeds all the bounds of credibility, it exceeds all the powers of credulity, to suppose that two such entirely independent and inconsistent schemes of construction should prove to be harmonious in their practical results. Such a coincidence is indeed physically possible, but the chance in favor of the possibility is less than one to some millions of infinities."

Thus reasons President Barnard. The question for discussion is therefore the Sun Distance, as monumentalized by the grand gnomon which stands upon the center and the border of the land of Ham.

It has been claimed by Pyramid students, for 30 years, that the vertical height of this monument bears a direct reference to this sun distance, that the circumference described by this height as a radius is not only equal to the square perimeter of the fundamental base, but that the length of this circumference or the square base contains as many times 100 *axial* inches, (*i. e.*, 500 millionths of the earth's polar axis) as there are *days* in the year. If this is so, then it is not only a *proof* of cosmic design, but one that is most appropriately built into the very parts of the monument, where, by the relations of the three things typified, and the form of the Pyramid itself, it naturally belongs.

If, however, President Barnard's sarcastic conclusion is correct, our link is more than bent; it is broken, and the chain of evidence a disconnected

one. But we unhesitatingly reply that this conclusion is absolutely erroneous, and we propose to show it upon his own ground. Let us quote it again and then we will be better able to discuss it. It is as follows:

"The Pyramid distance is therefore only about a million of miles too short; while probably the uncertainty which still attaches to scientific deductions is not so great as half a million."

Several things are here to be noted. In the first place there is the broad admission that even modern science rises from its most carefully studied problem, and from one upon which all the modern civilized nations have repeatedly united, sparing no expense, still doubtful by perhaps half a million of miles. This best modern deduction places the probable distance at about 92,500,000 British miles, with a probable increment of some thousands, if Professor Young's experiments upon light are fundamentally correct. We shall therefore accept this "best modern estimate" as to the sun's distance, convinced that a problem so faithfully and expensively studied, cannot have been solved with an error that shall ever hereafter cause the result to vary very considerably from 92,500,000 miles.

What now is the Pyramid sun distance? President Barnard is seriously in error in making it out to be the height multiplied by 10 raised to the 9th power. He quotes, it is true, Prof. Smyth as his authority, but Prof. Smyth *qualifies* this statement in that he expressly says that 9 on 10 is only "*practically*" the shape of the Great Pyramid. That is, not absolutely; 9 on 10 is an *approximation.* It is a wonderfully close and practical approximation, too, and it is one that is nearer the absolute truth than modern science is certain of the distance under discussion, by President Barnard's own admission. For the 9 on 10 theory of the slope places the sun distance at 91,840,011 miles, while that arrived at by modern science after all of its labors is really doubtful after its very first figures.

Now if the Pyramid is a π—Pyramid, as President Barnard admits "it undoubtedly is," it cannot be an exact 9 on 10 Pyramid. The question is therefore to determine *exactly*—I speak mathematically—what is the slope of the monument up the arris or hip lines, as they climb, from the fundamental, southeast, socket up towards the vertex of the cap-stone?

This slope is accurately expressed by the ratio.

$$\text{Slope of a } \pi\text{–Pyramid} = \frac{20\sqrt{2}}{\pi} \text{ on } 10$$

or carrying the calculations out to 14 places of figures, it is 9.0031631615711+ on 10.

This slope is so very close to the far more simple one, expressed in whole numbers, to wit; 9 on 10, that in common parlance the latter is generally used instead of the more cumbersome though absolutely exact decimal ratio. Either President Barnard knew this, or he did not. To say that he knew it would make him out as unfair in argument and scientific investigation, as upon page 22 he implies that Prof. Smyth has been. To say he did not know it is to point out that he has failed to comprehend the nature of the very question he is, with ex-cathedral vehemence, endeavoring to criticise.

Lest it may here be objected that the defining of a pyramid by its slope up the arris line, rather than directly up its face, is a fanciful method, and one without authority, it is to be noticed, that, as the latest measurer, Mr. Petrie, admits, "the designs of the various slopes that are met with, appear to be always a simple relation of the vertical and horizontal distance." It is in this very way that the Egyptian hieroglyphics themselves define them. For Ahmes, in his mathematical papyrus, defines pyramids by their "*sloping height up the arris edge, and their diagonal of the base beneath that line*" (Petrie): So that the natural and *Egyptian* method of stating a *slope*—a question which bears so strongly on the whole planning of the pyramid—is to say that it is built by the

$\frac{20\sqrt{2}}{\pi}$ on 10, template.

This, it will be noticed, increases the 9 on 10 approximation, by somewhat more than the .003th power, and gives us a function without error, and one to which President Barnard dare not advance an objection. With this expression for the slope the Pyramid sun distance (S) therefore becomes

$S = H(10)^{\frac{20\sqrt{2}}{\pi}}$, in which H is the height of the Pyramid.

Mr. Petrie is the latest measurer at Gizeh, and a disbeliever in most of the Pyramid theories. But, so far from overturning the cosmic theory of the Great Pyramid, as enunciated by Prof. Smyth, Mr. Flinders Petrie's work has magnificently endorsed it. His measurements of this building are throughout so nearly identical with those of Prof. Smyth that they prove the entire honesty of the latter, and fully corroborate all the ratios which he and Taylor originally noted. It was the elder Petrie, his father, who first advanced this sun distance reference. It is not a little strange, therefore, that the son by his measurements should unwittingly and yet so thoroughly support his father's theory, in which he does not believe. The very valuable work which details Petrie's labors at Gizeh should be in the hands of every one now engaged upon the solution of this engrossing problem. Especially should the opponents of the cosmic theory read and study it more closely than their own writings show they do. Now the careful measurements of Mr. Petrie enable us to determine the ancient height of the Pyramid from the floor level of the southeast or lowest socket, to the summit of its very capstone. He gives the data as follows:

From vertex to pavement level	$=5776''.0 \pm 7''.0$
" pavement to s e. socket level	$=\ \ 39\ .9$
∴ Petrie's height over all	$=5815\ .9 \pm 7''.0$

That is, it is practically 5816″. with a possible seven inches of *doubt* in either the positive or negative direction.*

Now if we add less than one half of the margin of error, actually here allowed by Mr. Petrie, to his own height of this ancient monument, we shall obtain the very height always claimed for the monument by maintainers of the cosmic theory. The height claimed by them is $5818''.62+$ British inches, which is equal to $5813.01 \pm$ Pyramid inches. Each of the latter is $.001\pm$, greater than the present British inch, and is an even 500 millionth of the earth's polar axis.

Expressed accurately by a circular and circummetric function, and for such a π–Pyramid this height is

$$H = \frac{180.\ A}{\sqrt{\pi}} = \frac{32400''}{\pi\sqrt{\pi}} = 5818''.622870+$$

in which A is the "analytical unit" $(57.29°+)$

Let us now treat this height, which from its possibility of exact mathematical expression is absolutely without error, by the equally absolute arris slope of the Pyramid just determined. The function for the sun distance will then be accurately as follows:

$$S = H\,(10)^{\frac{20\sqrt{2}}{\pi}} = \frac{32400''}{\pi\sqrt{\pi}}(10)^{\frac{20\sqrt{2}}{\pi}}$$

$$= (5818''.622870+)\ (10)^{9.0031631615711+}$$

but $(10)^{9.0031631615711+}$ equals the number whose common modern logarithm is

$9.0031631615711+$

since the logarithm of 10 is 1. Thence taking the common logarithm of H and adding it to this logarithm we shall have the logarithm of the required height in inches.

Thus,

$$\text{Log. } H = 3.7648202012654013581810 7$$

$$\text{" } (10)^{\frac{20\sqrt{2}}{\pi}} = 9.0031631615711+$$

$$\text{Log. } S = 12.7679833628365$$

$$\therefore S = 5861157\ldots\ldots''$$

$$= 92{,}505{,}634\,..^{*} \quad \text{miles!}$$

This remarkable result, which tallies so closely with Prof. Newcomb's estimated "probable sun distance" (92,500,000.± miles), as quoted so sarcastically by President Barnard against the mistaken 9 on 10 approximation, *is calculated to hammer at least one link of the chain of evidence into perfect shape upon the anvil of every candid judgment.* Nor is there a single one of the points of real pyramidal significance, which have thus again

* Mr. Petrie's measure has thus admittedly a possible error of $\pm 7''.0$. Upon page 15 of the introduction he says: "The probable error of all important measurements is stated with the sign ± prefixed to it as usual" . . . And further on he says, "and I will only add a short definition of it as follows: The probable error is an amount on each side of the stated mean, within the limits of which there is as much chance of the truth lying as beyond it."

With these statements, which show the accuracy with which Mr. Petrie accomplished and records his splendid measurements, we are ready to continue our examination of the subject.

* The number corresponding to the logarithm of the result has only been calculated to the seventh figure of the inches, because of the difficulty attending the process. It is calculated far enough however to avoid error greater than unity in the *miles.*

been disputed and put into controversy by President Barnard that will not yield to the sledge-hammer of mathematical truth, in this same manner!

It is apparent that the above argument would not be affected in the least by the most extreme refinement of computation. For an error of 200 feet in the earth's polar semi-axis represents 1000 miles or so in the sun's distance, and an uncertainty of a second in the parallax involves about 100,000 miles therein. The pyramid pronounces in favor of a solar parallax of $5''\sqrt{\pi}=8.''86226925+$, a number which is ten times the well-known "constant" used for obtaining the equality of squares and circles. This is exhaustively shown by Mr. Chas. Latimer, C. E., in the March (1883) number of the *International Standard*, where he also points out the fact that the base of the Pyramid

$$=100\frac{81''}{\frac{1}{2}\sqrt{\pi}}=\frac{8100''}{.886226925}=9139''8712581$$

Now it is a remarkable fact, perhaps more remarkable than any we have yet considered, that the height by which we have just determined the true sun distance, *demands* for the perimeter of the square indicated by the level of the south-east, or fundamental socket of the pyramid, a measure of exactly

$4\times$ (9139''.8712581+) =36559.''4850324 (Brit. in.)—a distance which reduced to pyramidal inches, or to 500 millionths of the polar axis, is the year number (365.2422)$\times$100.

This number, 9139''8712581+, has always been claimed by modern "pyramid students" as the actual fundamental base side indicated by the Pyramid. It is now proved to be so by Mr. Petrie's splendid measurements, and is shown above to be a true circular and circummetric function. The latest measurer at Gizeh, Mr. Flinders Petrie, claims, however, that the true base of the Pyramid is but 9068.8'', in which connection it has been lately remarked; "it had been a fundamental article in the Pyramid religion that the base should measure just 9140 British inches, and as it proved to measure only 9068.8, that with this determination, the beautiful union of the *sacred* cubit (25.'') and the length of the tropical year (365.242) melts away into thin air."

But this by no means follows when we get at the true facts of the case. Mr. Petrie's base (9068.8 inches) is that of the Pyramid measured horizontally along the upper surface of the *pavement* which surrounded it. It is not that of the fundamental square indicated by its lowest or south-east *socket* level. For *reasons of his own*, Mr. Petrie has *assumed* the pavement base as the real one to be studied. It was no doubt set out with most beautiful skill, and with a manifest object as to length. But it is the *fundamental* square that pyramid students have always maintained as of tropical year significance, and the *total* height of the monument from this fundamental level up to the vertex of its capstone as of solar distance import.

Upon page 38 of his "Pyramids and Temples of Gizeh," Mr. Petrie admits that "the sockets were cut to receive the sloping face, which was continued right down to their floors *beneath the pavement.*" . . . "Hence the sockets *show the size of the Pyramid where it was started from varying levels, which were all under the pavement.*"

Mr. Petrie further gives as the measure of the sloping line from the south-east socket up to the north-east socket, the length 9130.8''±(?). Pyramid students find that rigid mathematics demand 9131''.05+—a difference of less than .3''! Now 365.242$\times$25 (that is the year number by that (25) of the "sacred cubit:")=9131''.05. Hence this sloping line from the fundamental socket to the one next to it, expresses the required cosmic ratio in pure and simple figures. As it is a *sloping* line its mathematical significance is that of *ratio*, a fact which should not be lost sight of in this discussion.

Again, the sloping line being 9131''.05, the *horizontal* one from the south-east socket to the arris line produced through the north-east socket—*i. e.*, the base side of the *fundamental* square—is exactly 9139''.87+inches, or is the functional value demanded by pyramid students, *and thus again proved by Mr. Petrie's measure.*

Against the possibility of such a coincidence President Barnard claims, in the closing paragraph of his argument, that the chances are more than "*some millions of infinities to one.*" Yet here it is President Barnard, along-side of the true sun distance, linked to the true solar parallax,

and linked to each, in a cosmic monument, by the actual and modern π value, which was unknown and unused by the ancients. The question therefore for the candid and unbiassed man to answer, is, whether he will stultify himself at the mandate of such investigators as have yet arrayed themselves against the cosmic theory, or admit the monument to be a wonder past the ken of human intellect.

While I am willing to admit that there is much mistaken enthusiasm displayed by pyramid students in their engrossing study, it is nevertheless a fact that the study of this monument is opening up the whole topic of Metrology in a way that sets it before the world as the veritable science of sciences. Its students now include some of the most earnest men of both Church and State, and their investigations have long since raised the "Solution of the Pyramid Problem" far above the discussion of mere coincidence.

Mathematically speaking, there are no such things as "coincidences." In this rigid science "what is must be," and the deeper we examine the Great Pyramid the more our conviction grows that it is a consummate exponent of universal science, or *Metrology*.

Mr. Barnard finally concludes that while it is "indeed physically possible, that two," and we might add that *several*, "such entirely independent and inconsistent schemes of construction should prove to be harmonious in their practical results," still it would "exceed all the bounds of credibility, and exceed all the powers of credulity" if they should prove so. *But they do prove so*, hence as facts they are credible, hence too they being facts so physically beyond the range of accident, our credulity must cease, and in its place give room to honest conviction of magnificent design and, if it be not possible that such should be of human origin, then we must yield to our convictions and admit the overruling guidance of a hand that wrought far wiser at the Pyramid than the architect himself. If President Barnard and his school decline to accept this alternative, and we challenge them to dispute it, then they must gorge themselves with "several millions of infinities" in the presence of all right-minded men, and in a state of torpor digest their unwholesome and dyspeptic morsel.

To what purpose therefore shall we further discuss phases of this controversy that have long since been worn out. If the opponents of the cosmic theory have any *new facts*, to relate, which militate against the premises we base our faith upon, we ask them in the interests of science to show them forth. All searchers after truth desire to know them, but until they have, it is far better not to dip their pens in simple ridicule and innuendo, and attempt to wreck a Pyramid, against whose huge proportions few minds can measure themselves with any great advantage.

THE DEFECTS OF STEAM BOILERS AND THEIR REMEDY.

By Mr. A. C. ENGERT.

From "Iron."

Steam boilers are used as a medium to convey heat, or the accumulated force produced thereby, to an engine for the purpose of moving machinery to do certain work. The heat rises from the burning fuel within the boiler furnace, and penetrates the metal to heat the water in the boiler to 212° F. so as to form steam; but before its actual formation 966° F. has to be absorbed. Steam has no power to move a piston at such a low temperature, therefore more heat is required to produce the necessary force, and the higher the degree of heat contained in the water and steam, the more pressure will the steam exert on the piston when allowed to enter the cylinder. It is of the utmost importance to have perfect combustion, so that the whole of the heat may enter the water in the boiler. For this purpose various shapes and forms of boilers have been invented, but the Cornish and Lancashire types are found the most convenient for general purposes. Now 1 lbs. of good coal is capable of evaporating 15 lbs. of water,

but these boilers are only capable of evaporating one-third or at the best one-half of the quantity of water they should do in proportion to the fuel consumed (which is far too small a proportion), owing to the flame and heat wave rushing through the flues too quickly for the heat to thoroughly penetrate the metal. Improvements have, therefore, been introduced, such as Galloway and other cross tubes, in the Cornish and Lancashire boilers, which have proved to be very advantageous in saving fuel, so long as they are kept clean. But even with these improvements the average evaporation is not much more than half that which theory shows it should be owing to incrustation. This evil of incrustation, together with unequal expansion and contraction, and the corrosion in boilers, are hindrances which ought to be removed. In the author's opinion several of these evils are due to the construction of Cornish and Lancashire boilers. For instance, the ashpit, which is used to convey air to the burning fuel in the furnace, allows cold air to enter which keeps the bottom part of the boiler cool, and stays the circulation of the water within. If warm water even be fed into the boiler a part of the heat is again lost from the above cause, and the heat supplied to the bottom of the boiler is also partly lost, so that the lower part of the boiler is almost entirely useless for forming steam. Another trouble arising out of this evil is the unequal expansion of some of the plates. The top part of the boiler being hot and the bottom cool, causes great strain at various seams, as the expansion and contraction are continually affected by the varied draught or temperature, often loosening rivets and causing leakage, and endangering life and property. Another bad feature in this description of boiler is that the bottom of the flue and the shell being very close together it is hardly possible to clean those parts properly. This is of great importance, as on that particular part the most settlement takes place, the water being there almost stationary.

Among the general evils to which boilers are subject, incrustation is one of the principal, because all waters contain certain impurities which settle in the boiler, as the heat cannot dissolve nor drive them off with the steam. These settlements remain generally where the steam is formed, and get baked into a hard scale on the plates, but mostly on the crown of the flues and conical tubes. As this scale is a non-conductor of heat, it requires 15 per cent. more coal when the scale is only one-sixteenth of an inch thick; and when it is a quarter of an inch thick, 60 per cent. more coal is required. It is not only the coal which is thereby wasted, but the water is kept away from the boiler-plates, which become overheated, and eventually have holes burnt in them. To prevent incrustation, various solutions and many other remedies have been tried. The author desires to draw attention to the remedy which the chairman of the Manchester Steam Users' Association has recommended. This consists in putting 3 lbs. of soda ash every day in the feed water of a 50 horse-power boiler, and to frequently blow off. Besides this, he recommends the Porter-Clarke process, which consists in putting lime water into the feed water, which throws down all the carbonates, and the water is then filtered and ready to be pumped into the boiler. Still, this process does not touch the sulphates.

Another trouble with boilers is the formation of smoke and the loss of unconsumed gases. In reference to this, the author had the honor, in June 1881, to read a paper before this society "On the Prevention of Smoke"; he also sent a letter to the editor of *Iron* (which was published in that paper for December 21, 1883) entitled "The Cause of Smoke," of which the public has never been informed. A few points therein may, perhaps, be restated here, as some of the younger members of the profession may have thought the subject too unimportant to be enquired into. The author wrote as follows: "When fresh coals are placed on the fire in an open fire grate smoke rises directly. The cause of this smoke is not very far to seek, as it will be easily understood that before the fresh coals were put upon the fire within the grate, the glowing coals radiated their heat and warmed the air above, and thereby enabled the rising gases at once to combine with the warmed air to produce combustion, but since the fresh coals are placed upon the fire these coals absorb

the heat, and the air above remains cold. The fact is that these volatile rising gases cannot combine with the cold air for combustion, still a combination does take place in the following way: The cold air in the act of combination absorbs a part of the warmth of the rising gases which they cannot spare, and therefore they (the gases) must condense, so much so that small particles are formed, which aggregate, and are called smoke, and when collected form soot; but so long as these particles or gases are floating they cannot burn or produce combustion. Of course the invisible hydrogen gas rising from the coals with the smoke would burn easily enough, but it must be first lit before it can burn." The above sentences only refer to open fire grates; in furnaces smoke and waste of gases may be caused by too small a quantity of air, so that there is not enough oxygen to satisfy the rising gases, or there may be too much air, which, whilst passing through the furnace, absorbs heat and thereby impoverishes the combustion. In the paper on the prevention of smoke, read before this society, the author expressed a strong opinion that smoke once formed could not be consumed, and gave his reason, and he finds the following in a work frequently consulted by boiler makers: "We see, then, how palpably erroneous is the idea that smoke once formed can be consumed in the same furnace in which it is generated, and how irreconcilable is such a result with the operation of nature, and it is only the cooling down of carbon which produces smoke." Here then again smoke is attributed to the cooling down of the gases, and the author thinks the cause not only of the loss of a few grains of carbon and the other invisible gases (which amount often to a high percentage) which go out with the smoke, but also the trouble and unhealthiness produced by the smoke cannot be referred to too often. It is, of course, well understood that cold air must be prevented entering the furnace, and for this purpose mechanical stokers have been invented, not only to prevent the formation of smoke, but to save fuel. Experience, however, has taught us otherwise. Referring to the Manchester Smoke Abatement Exhibition, *Engineering* of April 28, 1882, after stating what the various mechanical stokers profess to do, observes that very many mechanical stokers are thrown out of use after a time, and the old hand-firing again resorted to. It is also remarked that though the machines are pleasing and satisfactory at first, the main result in the long run is that the mechanism is troublesome, wasteful and costly. Later on it is stated that "it would be interesting to know the actual number that has been fitted to boilers during the past five years, and in how many cases they are still at work." In the report of the Manchester Steam Users' Association, April 24, 1883, is the following: "The question of smoke prevention, and the relative merits of mechanical and hand firing, had been carefully considered by the association, and the conclusion arrived at was that, as regards economy, the two modes of firing gave practically the same result; as many as fifty-five mechanical stokers had been removed from boilers under inspection. To prevent smoke by hand firing, nothing out of common was wanted, but only a reasonably fair draught, a reasonably fair boiler, regular firing, and the admission of a little air above the firebars to secure the combustion of the gases." In the report of the Jurors' Committee of the Smoke Abatement Exhibition, it is stated on page 25, as to mechanical stokers, that "most of them require occasional assistance by hand," thus showing that they are still open to further improvement. In the above report it is stated, on page 27 (Firebars, fire-bridges, furnace-doors, &c.), that "the committee are of opinion that any assistance by which air is introduced with the view to complete the combustion either of gaseous or of solid fuel is objectionable, and is not likely to lead to the most economical results."

These statements of high authorities support the author's opinion that smoke cannot be burned in the same furnace where it has been formed, and much less is any furnace door able to produce complete combustion of the fuel burning within the furnace. In fact, entire combustion is almost beyond the means of man, in an ordinary furnace. Still, improvements have been made by introducing warm air, to combine better with the rising gases of the burning fuel. But even this is no easy matter, considering

that 150 cubic feet, or 22 lbs., of air are required for each pound of coal burnt; and it is a fact that the carbon requires great heat before it can be burnt, and further, that all solid fuel formed into gases and compressed gases while expanding absorb a large quantity of heat before they can burn. On this subject, *Engineering*, of December 2, 1881, says: "Total combustion means, not merely the rendering the products of combustion invisible, it means the conversion of the carbonic oxide produced into carbonic acid." Another author says: "The carbon burning in the flame has not completed its combustion, and it is only the high temperature of hydrogen burning which will enable the carbon to combine more readily with the oxygen in the air." It is only the clear white flame which will show that combustion is in its proper condition and everything is well heated. To prove that the carbon in the flame is only completing its combustion may be seen by the flame of a gas jet or of a candle, which gives a very white light, as, for instance, the Siemens gas lamp. But if a little air be allowed to blow in from the bottom, then the white light will blaze out in a long dark red flame, and give little light, but plenty of smoke and soot. Again, if a plate be held over a gas or a candle flame, carbon, *i. e.*, soot, will settle on it, and the deposit is increased when the plate is held lower in the flame, in fact the burning of carbon in a flame is only one of the stages of combustion, and when combustion is interrupted or incomplete it produces smoke, which is increased, while the invisible steam formed by the hydrogen will condense and cling to the dust of the carbon. This can be proved by the flame in a furnace; the lowest part of the flame where the carbon has just combined with the oxygen is generally much darker, even when the top is quite white, and thereby gives the greatest heat of some 2000° F., and when the flame is entering the tubes of a marine boiler, the bottom tubes are getting choked with soot, and the top flues, owing to the white flame, remain clean, and produce the heat required for forcing steam. When fresh coals are placed in the furnace, the stoker generally leaves a small quantity of fire on the dead plate upon which he places his green coal, and then closes the furnace door. This method the author thinks entirely wrong, as the heat from the fire underneath drives out the gases from the green coal in such rapid succession, that it is almost impossible for combustion to take place, even if the materials were ready for combustion. Such, however, not being the case, most of these valuable gases escape and are unproductive. If the fire on the dead plate were raked to the front near the door, and the green coal placed on the dead plate between the two fires, the small quantity of air entering the furnace door when shut would be warmed, and would ignite the rising gases from the green coal. At any rate, the first gas rising from the green coal is generally hydrogen, and as this gas has a greater affinity for oxygen than for carbon, it takes the first supply to form invisible steam and producing the greatest amount of heat whilst burning, thereby preparing all the other gases for proper combustion. To carry out this plan, the dead plate might be made a little larger so as to receive more coal at longer intervals, but the carbon gas at first very seldom combines with more than eight volumes of oxygen, forming carbonic oxide, as the carbon gases have to be formed from the solid carbon, and only afterwards while burning combine with eight more volumes of oxygen to form acid. Of course, if the draught is slow, which is always better for proper combustion, and if there be more carbon gas within the flame, then another six volumes of carbon gas is absorbed, and oxide is formed again. This then would be something like proper combustion, and would produce the heat required. But where is the quantity of warmed air to come from in the Cornish and Lancashire boilers? As the jurors state, in their opinion "air ought not to be allowed to enter above the firebars." Some very elaborate furnaces with hot air chambers have been built, but they are so expensive, and occupy so much space, that they are rarely employed. The atmosphere passing through the firebars, and incandescent fire above, is not at all times sufficient for complete combustion, especially when the draught is weak; and as it has been shown that burning carbon is taken up by another eight volumes of oxygen, it is almost necessary to apply

warm air above the firebars if the proper combustion of all the gases is to take place. The densest smoke is formed when stoking is commenced, or the partly burned coals in front are pushed backwards on the firebars. The coals now disturbed having been warmed and their pores opened, the previously confined gases rise in a mass, but meeting the cold air entering partly from the open fire-door and partly through the firebars, the gases condense and form smoke. To save this great loss of gases, and to prevent the formation of smoke, the damper ought to be nearly closed before the furnace doors are opened. If this plan is not adhered to, the owner of the boiler will not only lose all the gases as stated, but in addition some 8 lbs. to 10 lbs. of coals, to make good the cold which has entered the furnace and flues by the door.

Priming is another trouble common to boilers in general, and although a very important matter, the author has been unable to find any reference to this subject even in the most important works on boilers. He, however, found in a paper read before this society by Mr. Wm. Major, on April 9, 1877, the following: "It is certainly humiliating for the profession to be obliged to admit that one hundred years after the introduction of the steam engine they are still unable to subdue an evil so generally experienced as priming of steam boilers; yet such is the case, as proved by the *Serapis*." Further on it is stated that tallow and other remedies have been tried with various results, some doing harm to the boiler plates. It is, however, stated that petroleum, mixed with the feed water according to Mr. Major's invention, proved perfectly successful, as shown by a letter from Copenhagen, about one gallon of petroleum being used per day in a 30 horse-power boiler. Beyond these statements very little is said about the cause and remedies of priming. The author will now give his opinion and experience of priming in boilers. The warming up and starting of an engine in the morning requires a large amount of steam, as considerable condensation takes place at first, more especially in the winter. The great quantity of steam taken from the boiler in so short a period very often reduces the pressure of steam within the boiler some 25 to 40 per cent., and considering that the flues by that time are not very hot, and are not able to form steam, the whole formation of the steam required is thrown on one small plate or space just over the bridge of the Cornish or Lancashire boiler. In fact, this small part of the boiler has produced or formed the whole of the steam and pressure within the boiler, and therefore this part must be very hot, and the water close to it absorbs more heat for expansion to form steam, and is consequently lighter than the water just above it, and possesses greater accumulated heat for the moment than the steam bubbles already formed. The heated water, with the lighter steam bubbles, are therefore thrown up together, when the pressure from above is suddenly removed, and forced into the engine. The working of a vertical boiler may serve to make this clearer. The steam formed having to force its way up through a column of water from $1\frac{1}{2}$ to 3 feet deep, of course produces some pressure, and the water on the top being cooler than that at the bottom, the single bubbles of steam are hardly able to force their way up, and a combined effort is required (which may be said to cause a convulsion within the column of water) for the steam to raise itself, and then the superheated water is thrown up with the steam. This so-called priming in the vertical boiler is not seen in the water gauge so long as the water is kept low, say about 3 inches in the glass, but if the water be pumped as high as, say, 5 or 6 inches, then the water thrown up with the steam shows itself in the glass from the top. This, then, proves that the water forced up with steam will by gravity fall back in about a space of 3 or 4 inches from above the water line, and the steam so cleared will show very little priming. Pure water will, no doubt, prevent priming to a great extent, but where boilers are forced or the water stands too high in the boiler, then the convulsion will be stronger, and a higher space for the steam to clear itself will be required. These facts prove two things—firstly, that in most instances the heat is applied on too small a space, and thereby harm is done to the boiler; and, secondly, that the steam space above the water line is insufficient. These two conditions not only destroy or do harm to many boilers

and engines, but cause a loss of fuel and power. The best means for the prevention of priming will be explained later on.

The author thinks too little attention has been given to the air and gases with acids contained in the feed water by steam users in general, as these acids not only corrode the boiler plates and produce galvanic action with the grease returning to the boiler with the condensed steam, but the gases accumulating in the boiler amount to something more than is generally supposed. All water contains at least 2 to 3 per cent. of absorbed air and gases; such air and gases being continually pumped into the boiler accumulate. It is known that all gases are by gravity heavier than steam, the steam being on the top in the boiler is allowed to pass from thence to the engine, the gases remaining behind, and, as carbonic acid gas is the heaviest gas, it takes the lowest place. Now, a 50 horse-power boiler will use about 3,000 gallons of water per day; then there would be as much as 14½ cubic feet of various gases accumulated, and in a week some 80 cubic feet. These gases can only be expelled from the boiler by frequent blowing off; and if this be neglected, the gases and acids accumulate to a very great extent; and the author is of opinion that if an explosion then took place, it would be much more violent on account of the accumulated gases. They increase in volume as 1 in 490 at every degree F., so that at 50 lbs. pressure the accumulated volume of gases will nearly be doubled, and thereby give an after pressure to the steam to blow the boiler to atoms. The Manchester Steam Users' Association and other authorities have expressed the opinion that there must be something beyond steam pressure in many explosions. The return side and bottom flues of a boiler ought to be rounded off, as all corners prevent the proper flow of the air and heat waves. A few bricks sticking out in the flues from the brick walls will throw the heat-wave towards the boiler.

The author having stated some of the existing faults and their remedies in Cornish and Lancashire boilers, will now explain the improvements made in a boiler designed by himself, which has undergone some very severe trials. The object of the author was principally to do away with the ashpit; to prevent, if possible, incrustation; to extract from the water all gases; to prevent unequal expansion; to produce dry steam, and, by having better combustion, to prevent smoke. To obtain these results, he designed and had manufactured a boiler* in which two flat flues are placed one above the other in a cylindrical shell 16 feet 6 inches long by 7 feet diameter, of which the top flue is 4 feet 8 inches wide by 10 inches high, and the other 4 feet 6 inches wide by 10 inches high, the top one being stayed with 24 and the bottom one with 33 3½-inch vertical tubes screwed into the fire-plates and expanded. These two flues have one fifth more room for water and steam than the two flues of a Lancashire boiler, the top flue having its front bottom plate slanting downwards to make room for the firebars and furnace. On the front of the boiler a cast-iron box is fixed with the bottom open, having doors in front with slots and slides and perforated baffle plates. The firebars rest in front on a strong bar within the cast-iron box, and the back end of the firebars rest on the top end of the slanting flue. The front ends of the firebars are turned up to prevent the fire falling out. A sheet-iron curtain hangs down, so that when the doors are opened the fire is not exposed; when firing is required, the curtain is raised, and the damper is nearly closed automatically, so as to prevent cold air rushing into the furnace and flues. On the back end of the boiler there is a closed tank, 4 feet 8 inches wide, extreme height 4 feet, and 1 foot 10 inches deep. The water is supplied by gravity from a higher cistern, and a 2-inch pipe is carried from the tank through the roof, for the purpose of discharging the air and acids. The firebars sloping towards the front were designed so that the air should not merely pass through the firebars, and then rise to the boiler plate, but that the burning gases, drawn towards the flue, should continually meet and amalgamate with the other gases and meet the warm air coming through the slots in the front doors, so as to produce carbonic acid close under the boiler-plates, and to evolve the greatest heat at the proper places. The flame or heat waves in their

* This boiler is described and illustrated in *Iron*, vol. xxii., page 309.

passage are retarded by the vertical tubes, which they embrace, and thereby spread the heat to the top and bottom plates; the other part of the flame rushing by will do the same duty by the next tube, and so on to the end of the top flue. Here the heat wave is obstructed by a water tank for boiling the water contained within it, and the same process goes on at the bottom flue. Passing out at the front, the heat is led to the right side flue, returning under the bottom of the boiler, and passing to the left side towards the damper and shaft. The water does not remain long enough in the tank to be sufficiently boiled to throw down the carbonates and sulphates of lime, and therefore a live steampipe is carried from the boiler into the tank, and enters a large 4-inch pipe, which, with 50 lbs. pressure, will produce close to the pipe some 240° to 250° F., which heat will throw down the carbonates and sulphates (which are drawn off below) and send the acids and air out of the tank. The feed-water supply is taken from the hottest place over the pipe and is pumped into the boiler, and as this water is almost pure, and at the boiling point, it produces no settlement or scale within the boiler.

The steam supplied to the water tank is then led by a pipe to the front under the firebars, and allowed to escape in small jets for the purpose of warming the air under the grate. The steam passing through the incandescent fire will be partly dissolved into its two elements, oxygen and hydrogen, of which the oxygen will at first fly to the carbon, and the hydrogen will burn above with fresh oxygen again to invisible steam, which, if collected, would produce nearly a ½ ton weight of water from a ton of coals, if proper combustion had taken place. The steam jets are principally for the purpose of obviating the necessity of a very strong draught. The damper being half closed to prevent the heat from entering the chimney, the quantity of steam supplied under the front bars is very small, for if a large supply of steam was used it would become superheated by the burning fuel, and rise by its gravity close under the boiler plate, thereby preventing the heat from penetrating the metal, and proving that steam ought never to be employed above the firebars. The vertical tubes after one year and a-quarter of work are found to be as clean as if they had only just been put in. The circulation is so rapid there is no settlement on the bottom of the boiler. On the top flue only there is found a small quantity of sediment, which is easily removed by a water hose, and the scum on the sides of the boiler can be easily brushed off. Another advantage is that the bottom of the flues produce almost as much steam as the top, because no stationary steam globules are permitted to accumulate in consequence of the rapid circulation through the vertical tubes, in which no settlement or scale can attach itself. However large the flat flues are made, it is impossible for them to collapse on account of these vertical tubes or stays. The total heating surface is 577.7 square feet, and the grate surface 13 square feet. There are, therefore, 44.4 square feet of heating surface per square foot of grate surface. The author finds, that by a slow combustion and a gentle draught, more heat is evolved and penetrates the metal, and that therefore more water is evaporated per lb. of coal.

There being no ashpit in this boiler, and the boiler being entirely bricked in, no unequal expansion can possibly take place. As no cold air is allowed to enter the furnace, no smoke can arise except at the moment the curtain is let down and the damper raised; but this vapor is so trifling that it is hardly worth mentioning. A boiler on this principle was laid down by the author for driving the machinery at his works in Three Mills Lane, Bromley-by-Bow, in December, 1882, and has been tested by several independent engineers, amongst others by Mr. W. H. Maw and Mr. D. K. Clark. With this boiler there is no priming, dry steam being produced (as stated in *Engineering* for September 14, 1883), tests having proved it to be thoroughly dry. Mr. D. K. Clark, in his report, states: "I tested the steam produced each day for dryness; it proved to be dry and free from priming water." The explanation of the dryness of the steam is very simple, and is due to the large flat surface of water in the boiler, of about some 112 square feet area, which for the most part is only 3 inches deep, and having a heated flue-plate of some 80 square feet below,

and twenty-four vertical tubes, which with a volcanic action continually send up the steam formed within them, and that from below, caused by widely-distributed heat waves. Then there is such a rapid circulation that no pressure arises from a volume of water, and there is no force or convulsion present to form steam bubbles. With shallow water and well-distributed heat, priming is therefore prevented.

Thus the principal defects of boilers have been remedied by this new design. There is very little waste or ashes, no clinkers in general, and only a few cinders, which may be used again. The stoking is very simple, as the coals are placed almost in front, the bars are short, and slanting to the front. In *Iron* of October 5, 1883, it is stated by the editor that this boiler has realized the highest efficiency on record, and that it marks a new phase in boiler construction. In the *Times* of September 17, 1883, the editor favored the invention with a similar opinion. Mr. W. H. Maw and his staff made five tests during nearly six months, of which the author here gives the last. An elaborate report of the same was published in *Engineering* of September 14, 1883, in which it was stated that the boiler embodies a number of novel features, and produces rapid circulation through the vertical tubes, the effect of the curtain being very marked, and that as a rule there was no trace of smoke.

Results of Evaporation Tests, Aug. 31, 1883.

Duration 8. A. M. till 5 P. M., 9 hours.
Steam pressure, maximum, 50 lbs. per square inch.
Steam pressure, minimum, 39.5 per square inch.
Steam, mean, 45.5 per square inch.
Coal, total quantity burned, 1,015 lbs.
Coal, quantity burned per hour, 112.8 lbs.
Coal, quantity burned per square foot of grate (short bars), 8.68 lbs.
Ashes weighed, containing fragments of coal and clinker for which no allowance was made, 39 lbs.
Area of grate, 13 square feet.
Water, total quantity evaporated, 1,150 gallons.
Water evaporated per hour, 127.7 gallons.
Water evaporated per square foot of heating surface, 2.2 lbs.
Water evaporated per lb. of coal, 11.3 lbs.
Temperature of feed water, mean, 81.6° F.
Temperature of gases measured in flue between damper and chimney, 290° F.
Draught, mean, in inches of water, $\frac{5}{16}$ inch.

The National Smoke Abatement Association had two tests made by their engineer, Mr. D. K. Clark, who gave a minute report of the boiler in question, and from which the following figures are taken. The report is dated January 18, 1884.

Result of Evaporative Performance and Efficiency of the Engert Steam Boiler, London, 1883.

Number of Trial.	1.	2.
Date of trial	Dec. 20, 1883.	Dec. 21, 1883.
Temperature of boiler-house, average	59.3° F.	57.3° F.
Barometer Average	30.03 inches.	29.90 inches.
Duration of trial	8 hours.	8 hours.
Average effective pressure per square inch in the boiler	41.6 lbs.	36.6 lbs.
Net quantity of coal consumed at trial	1,064 lbs.	1,568 lbs.
Net quantity of coal consumed per hour	133 lbs.	196 lbs.
Net quantity of coal consumed per hour per sq. ft. of firegrate.	10.23 lbs.	15.10 lbs.
Ash (no clinker) residue	74 lbs.	84 lbs.
Ash residue per cent. of net coal consumed	7 per cent.	5.36 per cent.
Average temperature of water supplied for consumption	73.5° F.	70° F.
Quantity of water supplied for consumption	202.5 cubic feet.	236 cubic feet.
Quantity of water per hour	25.31 cubic feet.	29.5 cubic feet.
Quantity of water per hour per square foot of grate	1.95 cubic feet.	2.27 cubic feet.
Quantity of water per pound of coal consumed	11.85 lbs.	9.37 lbs.
Quantity of water per pound from and at 212° F.	14.18 lbs.	10.96 lbs.
Quantity of water per pound of combustible	12.73 lbs.	9.90 lbs.
Quantity of water per pound of combustible from and at 212° F.	14.90 lbs.	11.58 lbs.

Mr. Clark concludes his report with the following remarks:—"On the first day the boiler was worked at the usual pace to supply steam for daily requirements; on the second day it was forced by increasing the draught, in order to test still further the capabilities of the system. In point of efficiency the results

compare favorably for the Engert boiler. On the system of firing for this boiler, which does not demand more than an ordinary degree of care in management, smoke can be entirely suppressed. Shortly after the two days' tests were completed, the boiler was opened in my presence, and I found on inspection that it was entirely free from scale, and was otherwise in good order. I may add, in conclusion, that in my opinion Mr. Engert has produced a steam boiler of much merit, and that he has made a new and effective departure in steam boiler engineering."

The interior of the boiler has also been inspected upon two occasions by the engineer of the London Mutual Boiler Insurance Company, the last inspection having been made on November 9, 1883. Upon each occasion the inspector reported the boiler to be clean and free from scale or deposit.

In conclusion, the author would submit that the defects of steam boilers and the evils of incrustation, priming, and bad circulation are largely, if not wholly, due to faulty construction, and that he has succeeded in remedying these defects. He submits this with confidence, not so much upon his own authority and experience as upon those of independent engineers who have investigated the working of his boiler, and have reported favorably upon it.

THE FOUNDATIONS OF THE NEW CAPITOL AT ALBANY.

By WILLIAM JARVIS McALPINE, M. Inst. C. E.

From Selected Papers of the Institution of Civil Engineers.

The Author has not met with sufficient information to establish a rule for determining the load which may be safely imposed by a structure upon earth of a specific character and condition. The degrees of consistency and compactness in different kinds of earth and their mixtures, and, above all, the extent of moisture therein, so affect the supporting power as to discourage any attempt at a formula for practical use. The nearly universal rule seems to be, to depend upon the previous experience of the locality, or upon observations of structures supported on similar earths in like conditions; in fact, to guess at, what the Author believes may, in most cases, be determined with considerable precision, and avoid on the one hand the unnecessarily costly foundations which are so frequently observed, and, on the other hand, those inappropriate and insufficient foundations which cause the destruction of the superstructure.

He was requested ten years ago, to devise plans for the foundations of a large and costly State building, which had to rest upon soil apparently equable and stable, but which proved, on careful examination, to lack these qualities to a remarkable extent. It was also found that the earth, to a great depth under many portions of the foundations, received and parted with a considerable amount of moisture with the changing seasons. The circumstances of the case did not allow the use of piles or inverted arches; it was, therefore, necessary to spread the base of the walls over such an area as would afford the requisite sustaining power, and also to protect the clay and sand from any excess or deprivation of its natural degree of moisture, so as at all times to derive from it the same degree of support. The importance of the work warranted the expense of experiments to determine the questions above referred to. In the absence of any similar or equally extensive experiments, the author is induced to submit the present ones, in the hope that an explanation of the methods adopted, and the results attained, will prove serviceable.

The structure, though a single building, may be considered as a collection of a dozen large ones, with great differences of elevations, and weights upon the lower walls, and yet so bonded together as to require that the pressure of each of the parts should be the same per square foot on the earth beneath. This object has been fully accomplished; and when the

structure is loaded to the maximum extent of 200,000 American tons, the author believes that it will not compress the earth upon which it rests more than three-fourths of an inch, and exactly the same under every part thereof. The building measures nearly 300 feet by 400 feet on plan, and has three main stories and a basement. The lower walls are 110 feet high, but those of the corner towers, pavilions, and main tower, are of much greater height.

The ground covered by the structure sloped eastward at the rate of 1 in 25. The pit was excavated to a depth of 5 feet below the natural surface at the south-east corner, and 25 feet at the north-west corner. The excavation, together with the borings which were made in the bottom of the pit, fully exhibited the character of the earth. The lower strata (termed in the locality "blue clay," and "Albany clay") are more than 100 feet in thickness, resting upon the Hudson River Argillite (a clay state), the two forming the banks of the river for 30 miles of its course. The "blue clay" contains from 60 to 90 per cent. of alumina, the remainder is fine silicious sand. It also contains many nodules of clay, highly charged with carbonate of lime in the form of rings and discs about an inch in diameter. Overlying the blue clay was a mass of earth from 1 foot to 35 feet deep, composed of the same clay mixed with sand of different degrees of fineness, in proportions varying to such an extent as, when saturated, to render it in some places, a semi-fluid, while in others it was nearly pure sand. and very porous. This material occurred in veins and strata, large and small, above and below the level fixed for the foundation. One of the largest of these veins of viscid earth passed diagonally across the foundation, and at a depth of 6 to 20 feet below the bottom of the pit. It was 200 feet long, and from 5 to 25 feet wide.* Other veins and strata of less size, were found extending across the bottom, and sometimes terminating in pockets in the blue clay. Borings, from 10 to 30 feet deep, were made in several places below the bottom of the pit, which showed the substratum to be blue clay; and a well which had been sunk close by, to a depth of 100 feet, was entirely in the blue clay.

The earth in its natural condition at midsummer contained from 27 to 43 per cent. of moisture. When the samples were thoroughly dried and pulverized and again fully saturated (without dripping), they absorbed from 39 to 46 per cent. of water. The blue clay ordinarily held about 40 per cent., and when dried, again absorbed about 43 per cent. It was, therefore, as a rule, completely saturated in its natural state. It was upon this kind of earth that the subsequent experiments of the supporting power of the clay were made. The pure clay, obtained by separating it from the sand, weighed 116 lbs., and the sand so separated 80 lbs., per cubic foot; but, when they were again mixed in different proportions the weight of the mixture was less than the proportionate means between them. Earth taken from the same places as the samples, varied from 81.5 to 101.4 lbs. per cubic foot, depending upon the proportions of the clay and sand; and these weights show, to some extent, the relative supporting power of the earth at the places from which the samples were taken.

It was originally intended to support the structure upon wooden piles, of which a considerable number had been procured before the author was entrusted with the direction of the work. Many comparatively large buildings in Albany have been supported upon wooden piles driven into the blue clay or upon thick planks laid under the walls. In a few cases the wood used for this purpose has been found in tolerable preservation* half a century after it had been buried in the blue clay; but, generally, such timber was much decayed at the end of a quarter of a century; and several heavy buildings, after having stood firm for twenty years, began to settle, and the walls to crack, in consequence of the decay of the wooden supports and the unequal settlements therefrom. It appears that when the clay had been kept constantly moist, the wood did not materially decay in half a century; but, wherever the moisture was drawn off, the wood did not last more than twelve years. In this case, even if

* This vein was dug out, and replaced with clay and sand artificially mixed, moistened, and slightly rammed in layers, so as to render it as similar to the adjacent natural material as possible.

* In digging the trenches for the street pipes of the new waterworks at Albany, the author had occasion to remove many of the old pine water-pipe logs, of which only the sap wood was decayed. They had been buried in the blue clay for more than half a century.

a wooden foundation could have been arranged so as to be kept constantly wet, it would have ultimately decayed; and its use was, therefore, inadmissable. Cast-iron piles of white iron could be relied upon for a century or more, but would also have eventually decayed.

The use of sand and concrete piles, made by boring or driving holes into the clay and filling them with these materials, was also considered. For reasons which will subsequently appear, inverted arches could only be used under a part of the structure,* and it was deemed advisable to have but one system of support. The author, therefore, finally determined upon the plan which has been executed.

In most buildings, except where spires or towers are introduced, the weight is nearly equably imposed upon the several foundation walls; but in the Capitol the main and pavilion towers are much higher and heavier than the adjacent walls. The extremely heavy fire-proof floors, loaded as they will be frequently with dense crowds of people, books, &c., must necessarily carry their load to two only of the four surrounding walls, and, with some of the roofs acting in the same manner, will produce very unequal pressures upon the foundations.

The weight of the whole building and its contents when in use will be 200,000 American tons. The area of the base of the exterior and court walls, and the rear walls opposite, is about 24,000 square feet, and sustains an average of 6½ tons per square foot on the basement walls. The main tower, which weighs 30,000 tons, has an area of 2,508 square feet, equal to 12 tons per square foot upon its foundation walls. The weight on the foundation under the exterior walls of the corner towers is 47 tons per lineal foot; on the interior walls of the same towers, it is only 39 tons; and on the adjacent division walls, 23½ tons. Still greater differences in the weight on adjacent walls occur in other parts of the building, especially at the main tower, where the weight is 134 tons per lineal foot, and on the adjacent walls but 47 tons and 39 tons.

* It was necessary to arrange to carry two-thirds of the weight upon the exterior, rear, and court walls, which are separated 120 feet on two of the fronts, and only 90 feet on the other two. Inverted arches spanning three very unequal spaces would have imposed unequal loads upon the clay beneath, and their use would have defeated the design of distributing exactly the same weight upon every part of the clay beneath the structure.

Passing around the exterior walls of one quarter of the structure (the remainder being a repetition of the same sized walls), the weights to be supported per lineal foot are successively as follows: commencing at the main tower, 134 tons (which may possibly be increased); the adjacent walls are 47 tons per lineal foot for 60 feet; next, 44½ tons for 60 feet; next, 47 tons for 120 feet (turning the corner tower); next 44½ tons for 60 feet; next, 67 tons for 18 feet; and next, 50 tons for 52 feet to the center of the south or north front. On the rear of each of these walls, the interior wall is loaded with 39 tons, and the division walls with 8½ to 23½ tons per lineal foot.

The exterior walls of cut granite facing, backed with rubble and brick, average 150 lbs. per cubic foot. The floors, including the iron box girders, cross beams, brick arches and covering, average 24 lbs. per square foot. The possible weight of crowds of people upon the floors is taken at 100 lbs. per square foot; the snow upon the roofs, at 2 feet depth, is 12½ lbs.; and the effect of the strongest winds, which may at times be deflected perpendicularly against some of the roofs, is taken at 15 lbs. per square foot. The calculated weight which may come upon each of the walls is as follows: on the corner towers and front foundation walls, 47 tons per lineal foot; on the main east and west front, 50 tons; on the curtains, 44½ tons; on the ventilating tower, 67 tons; on the division walls, extending upwards through four stories, 23½ tons; on the partition walls of two stories, 13½ tons, and of those which extend one story high, 8½ tons, per lineal foot. The main tower is designed to be of stone, except the portion immediately below the dome, which, from being so high from view, was proposed to be made of iron. If it should be of stone to the dome, that change, together with some others, would increase its weight to 36,000 tons, equal to 14.4 tons per square foot at the base. Its footing stones were spread to 110 feet square, and the concrete to 125 feet square, and 5 feet thickness. The weight on the clay, with 30,000 tons, is 1.92 ton per square foot; and with 36,000 tons, it would be 9.3 tons; but it was arranged for an underpinning, if necessary.

THE EXPERIMENTS.

For the purpose of ascertaining the

sustaining power of the blue clay in its natural condition, two sets of experiments were made; in the first by pressure upon a square foot, and in the second upon a square yard, of the surface. The machine used was a mast of timber 12 inches square, held perpendicularly by guys, with a cross frame for the weights. A hole was dug, 3 feet deep, in the bottom of the blue clay foundation, 18 inches square at the top, and 14 inches at the bottom. The foot of the machine was placed in this hole, and weights from 2,754 lbs. to 23,784 lbs. were applied. Small stakes were driven into the ground, in radial lines from the center of the hole, and the tops carefully driven to the same level; and by means of a straight-edge any change in the surface of the ground adjacent to the hole could readily be detected and measured.

Table I. shows a continued settlement of the clay under the foot of the machine as the loads were added, but no change in the surface of the adjacent ground was observed until an hour after a weight of 11,844 lbs. had been applied, when an uplift of the surrounding earth was noted, in the form of a ring with an irregular rounded surface, the contents of which, above the previous surface, measured 0.09 cubic foot, which is equivalent to a displacement of 1.09 inch of clay in depth under the foot of the machine, or equal to one-fifth of the whole settlement which had then occurred.

TABLE I.

Observation.	Day.	Hour.	Duration.	Weights. Each.	Weights. Total.	Settlement. Each.	Settlement. Total.	
			Hours	lbs.	lbs.	Inches.	Inches.	
1	Mon.	5 P. M.	—	2,754	2,754	0.288	0.288	The weight of the machine.*
2	Tues.	9 A. M.	16	—	—	0.612	0.900	
—	"	9 "	—	2,820	5,574	—	—	First stone added.
3	"	10 "	1	—	—	0.528	1.428	
—	"	10 "	—	6,260	11,834	—	—	Second and third stones added.
4	"	11¾ "	1¾	—	—	4.752	6.180	Uplift noted.
—	"	11¾ "	—	3,250	15,084	—	—	Fourth stone added.
5	"	½ P.M.	¾	—	—	3.588	9.768	
6	"	1 "	½	—	—	1.728	11.496	
—	"	1 "	5 min.	2,890	17,974	0.060	11.556	Fifth stone. Immediate settlement.
7	"	1½ "	½	—	—	3.288	14.844	
—	"	1½ "	—	2,980	20,954	—	—	Sixth stone added.
8	"	2 "	½	—	—	4.128	18.972	Uplift noted.
—	"	2 "	—	2,830	23,784	—	—	Seventh stone added.
9	"	2½ "	½	—	—	5.184	24.156	
10	"	3 "	½	—	—	2.060	26.216	
11	"	4⅓ "	1⅓	—	—	1.300	27.516	
12	"	5 "	⅔	—	—	3.084	30.600	Uplift noted.
13	Wed.	5 A. M.	12	—	—	0.600	31.200	
14	"	8 "	3	—	—	—	31.200	No settlement after 5 A. M.

Observations 12 and 13 are not reliable.

* The first settlement, noted in observation 1, was due to the weight of the machine, and was not a compression, but only a leveling of the rough inequalities of the clay. The subsequent observation 2, of 0.612 inch, is the compression due to 2,754 lbs. This settlement occurred before 5 A. M.

When the weight had reached 20,954 lbs., and had rested for half an hour upon the clay, a further protrusion was noted. The form of the ring was the same as before, but with more irregularity of surface. The highest part of the protrusion was from 12 to 15 inches from the edge of the pit, where it averaged 0.3 inch high, and sloped off outwardly to an average of 4 feet from the center of the hole. This uplifted earth measured 0.606 cubic foot, which is equivalent to a displacement of 7.272 inches. When a weight of 23,784 lbs. had been applied, and had rested three hours on the clay the ring in the highest part averaged 0.5 inch high, in the same general form and extent as before noted. The amount of earth thus raised was 1.01 cubic foot, equivalent to a displacement of 12.12 inches under the machine.

Before the lifting of the earth surrounding the machine could have taken

place, the materials first displaced from under the machine were doubtless forced among the particles of the earth adjacent to the whole, and compressed that earth to some extent; and this operation was continued until the adjacent earth had become so compacted as to cause the lifts noted in the table. The author is of opinion that the compression of the earth below the bottom of the machine continued without any considerable displacement until after a load of 4,000 lbs. or 5,000 lbs. had been applied, and that then the displaced earth found space in the adjoining earth until the load reached 7,000 or 8,000 lbs., when the uplift became visible at the surface of the ground; but that meanwhile the earth directly under the machine was continually more and more compressed in some proportion to the weight added. The small area pressed upon facilitated the escape of the material into the adjacent earth, which weighed only 300 or 400 lbs. per square foot. If the pit had been deeper, or the piston larger, there would have been less displacement.

The second set of experiments was made with the same machine, to the bottom of which was framed a strong base, 3 feet square. The pit was sunk 2 feet deep into similar earth, and was 38 inches square both at the top and at the bottom. The stones were put on at intervals of an hour. There was no uplifting of the surrounding earth.

Table II. shows the remarkable regularity in the settlement as the load was increased, and a constant diminution of the increment as the earth became more compacted. At the 6th observation the weight per square foot corresponded nearly with the 2d in Table I., and the settlement was almost the same. The base was nine times as large, so that the proportion of escapement of the earth from beneath must at this time have been very small. It is probable, however, that if the weights per square foot had been increased so as to equal those in Table I., a similar uplift would have occurred, though of less extent. The author derived from the Tables the opinion that the extreme supporting power of this earth was less than 6 tons per square foot, and that the load which might be safely imposed upon the clay was 2 tons per square foot.

TABLE II.

Observation.	Weight.			Settlement.		
	Each.	Total.	Per sq foot.	Each.	Total.	
	lbs.	lbs.	lbs.	Inch.	Inch.	
Machine Placed.....	3,228	3,228	359	—	—	No settlement that could be measured.
1st stone added......	2,380	5,608	623	0.050	0.050	
2d " "	3,300	8,908	990	0.150	0.200	Estimated.
3d & 4th stone added.	6,960	15,868	1,763	0.166	0.366	
5th " "	2,830	18,698	2,078	0.134	0.500	"
6th " "	3,250	21,948	2,439	0.124	0.624	
7th " "	4,420	26,368	2,929	0.096	0.720	"
8th " "	1,190	27,558	3,062	0.080	0.800	
9th " "	2,320	29,878	3,320	0.025	0.825	

The notations of the settlement were generally made about an hour after the weight had been applied.

For the purpose of maintaining the clay beneath the structure in the same condition of moisture, a deep puddle wall was extended entirely around the foundation, not only to exclude an excess of water, which might reach it through the veins and films of sand with considerable hydrostatic head, but also to prevent the egress of the natural moisture through similar veins. Although the puddle wall was carried up to the level of the terrace which surroundsthe building, yet water might find its way along the face and down the outside of the walls, or possibly through some accidental break in the concrete floors within and surcharge the clay below. To prevent this, there was spread on the top of the clay, over the whole area enclosed, a depth of 6 inches of coarse screened

gravel, the effect of which will be that under the great weight of the building any excess of water in the clay beneath will be forced into this pervious gravel, and flow off through it to the drains which encircle and traverse the foundations. The necessity for these provisions will be apparent when it is considered that many of the veins of sand extend to the surface of grounds of much greater elevation than the foundations, and that they communicate with imperfectly built street sewers and water pipes, while the same or other porous veins extend beneath the surface to grounds which are much lower. Through these sources the clay under some portions of the structure might be charged with water, while that under an adjacent wall might, at the same time, be drained of much of its natural moisture, and thus entirely destroy the design of a foundation which should everywhere have an equal sustaining power. It is not an absolute settlement which is to be apprehended, but a greater yielding in one place than in another.

A common practice of builders who have occasion to erect high and comparatively heavy towers and spires, is to groove the lower part into the adjacent walls, so as to allow the heavier ones to slide in these grooves, without breaking the bonding stones. In the present case the demands of the architect forbad the use of grooving, and hence the necessity for the above provisions.

The main walls of the building are from 5 feet to 7 feet thick, where they rest upon the foundation walls, and bring upon them pressures of from 6 to 9 tons per square foot, which had to be reduced to 2 tons per square foot on the clay. This was accomplished by projecting each of the footing courses beyond those immediately above them. The rule was to commence with a load of 2 tons per square foot upon the clay, 3 tons upon the top of the concrete, and generally 4, 5, 6, or 7 tons upon each succeeding course of stone. The weight on each lineal foot of the top of the foundation walls, divided by the above pressures, gives the exact width of each course of the footing stones, as shown in Table III.

Table III.

Parts of the Building.	Load per Lineal Foot.	Required width of Courses.						Main Walls.
		Concrete.	Courses of footings.					
			1st.	2d.	3d.	4th.	5th.	
	Tons.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.
Corner towers, front	47	23 6	15 8	11 9	9 4	7 10	7 4	7 0
" " rear..	39	19 6	13 0	9 9	7 10	6 6	5 6	5 0
Curtains, front.......	44½	22 3	14 8	11 1	8 11	7 5	6 5	6 5
Central fronts... ...	50	25 0	16 8	12 6	10 0	8 4	7 2	6 5
Partitions, 4 stories..	23½	11 9	7 10	5 11	4 9	3 11	3 5	3 0
" 2 "	13½	6 9	4 6	3 5	3 0	—	—	3 0
" 1 "	8½	4 3	2 5	2 2	2 0	—	—	2 0

The large quantity of stone required in a short time—50,000 tons in four months—compelled a resort to a great many quarries, which furnished stones of different thicknesses, and made it necessary to modify the above exact arrangement; but the principle of the distribution of the load according to the vertical strength of the stone used was maintained throughout the foundations.

It was necessary to consider how far these projections could be made without danger of breakage of the projecting part of the stone. The pressure in this case tending to break the stone is that due to the weight on the wall above it, divided by the width of the wall and multiplied by the area of the projection, and to treat that result as a load distributed on a beam supported at one end.

To distribute the weight upon the footing stone courses with certainty, the beds of the limestone and granite were

dressed to close parallel joints, so that the weight of each of the upper courses should be carried out to the extremity of the next course below. The vertical joints were only required to be quarry joints, not exceeding 1 inch wide. For certainty and convenience of laying the masonry, the foundation stones were all required to be rectangular blocks, of from 18 to 24 inches in thickness, the breadth to be at least one and a-half time the thickness, and the length two and a-half times the thickness. The average size of all the stones was 31 cubic feet, equal to 2½ tons, and many of them were from 5 to 8 tons weight. In the foundations of the main tower the average weight of the granite blocks was four tons, and of the projecting blocks 7 tons. The footing courses were spread out equidistant from the lines of the center of gravity of the imposed weight above. The exterior stones of the three lower footing courses were all headers from 4½ to 7 feet in length. The longitudinal bonding was made by the interior stone, and in the upper courses, where the projections were smaller, by alternate headers and stretchers of the front stone, as well as the interior. The result of this bonding will be to distribute the weight, and equalize its pressure upon the clay.

The weight of the main tower was so much greater than that of the other walls, and the earth below it so much inferior, that the foundation was placed 7 feet deeper than elsewhere. With this exception, all the walls were commenced at the same level. The spaces between the main exterior, rear and division walls, and under the arches of the central court, were covered with a layer of concrete, made of screened gravel and hydraulic cement, 1 foot to 2 feet thick.

THE COMBUSTION OF FUEL IN FURNACES OF STEAM BOILERS BY NATURAL DRAUGHT AND BY SUPPLY OF AIR UNDER PRESSURE.

By Mr. JAMES HOWDEN.

From "Iron."

The various improvements in the steam-engine which have led, during the last twenty or thirty years to the great reduction in the ratio of fuel consumed to power obtained, have hitherto been almost exclusively confined to the motor, and scarcely, if at all, connected with the generator; the reduced consumption having been effected by the more judicious use of steam in the engine, and not by its more economical evaporation in the boiler. Putting aside the merely constructional improvements arising from greater experience, better material and appliances, steam boilers for land and marine purposes are practically the same as they were when the average consumption of coal per horse-power developed in the engine was about three times that of the present day. It may even be said that we have retrograded rather than advanced, as forty years ago a higher evaporative economy was prevalent in Cornwall than is found there or anywhere else now. In that district, in 1846, an evaporation was recorded per lb. of coal of 12.89 lbs. of water from 212°. In the marine practice of the present day the average evaporation per lb. of coal is probably not more than 0.6 of this Cornish economy, while in those high-speed steamships which maintain an average of about 17 knots across the Atlantic, it is probable that barely half of this evaporative duty is reached. This great falling off in evaporative economy in boilers of the present day must not, however, be ascribed to less knowledge, but to the different conditions and necessities imposed by great industrial progress. The conditions under which the high economy of the Cornish boiler was obtained are incompatible with marine requirements. They would also, as a rule, be impracticable or unprofitable if applied to land boilers, especially in populous districts. Time and working space are every day growing more valuable. A maximum of power in a minimum of space is being more and more sought for.

This demand is diametrically opposed to the essential conditions by which the high Cornish economy was obtained. The rate of combustion was from 3 to 4 lbs. of coal per hour per square foot of grate, accomplished by careful restriction of the air admission to the furnaces. The proportion of heating surface to water evaporated was from six to seven times that of the average in marine boilers. A comparatively low temperature in the high chimney gave an adequate draught for the slow combustion, and permitted the heating of the feed water by the waste gases after leaving the boiler. Add to these precautions the most thorough protection of the whole boiler from loss of heat by radiation, and we have the conditions by which the high evaporative economy was effected in Cornwall forty years ago.

Though the necessities of our day render this cumbrous and slow system unsuitable for our steam supply, yet it must be acknowledged that the fact of the higher evaporative power now required from boilers being obtained only with a great sacrifice of evaporative economy is inconsistent with the general advance in engineering science, and contrasts unfavorably with the marked economical improvements in the engine or motor. I hope, however, to show that this anomaly is not incapable of being removed, and that even a much higher evaporative power than now prevails may be had from boilers, along with a higher evaporative economy than is found in present practice, that, in short, an approach may be made to the unequaled economy of the Cornish slow combustion system with an evaporative power, it may be ten times greater. Experience has hitherto shown generally that, with slow combustion judiciously carried out, a high evaporative economy has been effected by natural draught, but as the rate of combustion has increased the evaporative economy has steadily fallen. Further, when combustion has been raised by forced blast to a rate much higher than is possible by natural draught, the evaporative economy has decreased in a still higher ratio. As it is important at this stage to elucidate the causes of this unsatisfactory result, I will endeavor to do so before describing how the difficulty may be overcome.

Combustion by natural draught in boilers at the rates now prevalent is necessarily more or less wasteful and imperfect, because the velocity given to the air supply, even with the sharpest draught, is insufficient to cause it to penetrate and mix with the fuel over the whole area of a furnace of ordinary dimensions, and further, because a very considerable portion of the heat of combustion is required to rarefy the air in the chimney to maintain the draught, this expenditure increasing with the rate of combustion. Unless, therefore, a much greater supply of air is admitted to the furnace than is required theoretically for perfect combustion, it is found that, owing to unequal distribution and imperfect mixture of the air with the fuel over the area of the furnace, part only of the oxygen enters into union with the combustible gases and carbon of the fuel, the remainder passing to the chimney unassimilated. The unavoidable consequence is that a considerable portion of the carbon leaves the boiler unconsumed as carbonic oxide. Smoke is also formed in large quantities, and though this objectionable product contains in itself but a small portion of carbon, it is always an indication of imperfect combustion, and of more important constituents of the fuel being wasted. On the other hand, if, in order to secure the more complete combustion of the fuel, an increased admission of air is made to the furnace, then the excess of air—which must always be largely beyond the quantity required for perfect combustion when properly carried out—reduces the temperature of the furnace, and consequently the ratio of evaporative power, and, what is still more wasteful, robs and carries off to the chimney a large percentage of the total heat of the fuel.

The wastefulness arising from imperfect combustion caused by restricting the air supply as described, may be estimated from the following data. When perfect combustion is effected by the chemical union of two atoms of oxygen with one of carbon forming carbonic acid, 14,500 units of heat are evolved from 1 lb. of carbon, but when from imperfect combustion only one atom of oxygen unites with one atom of carbon and carbonic oxide is formed, only 4,400 units of available heat are evolved from one lb. of carbon. The

loss arising from this imperfect combustion can therefore be calculated by ascertaining the proportion of carbonic acid to carbonic oxide in the waste gases, noting also the quantity of air passing away with its oxygen unassimilated. The wastefulness arising from admitting excess of air in order to obtain more complete combustion and reduction of smoke, is estimated by ascertaining the quantity of air admitted in excess. About 11 tons of air are required for the perfect combustion of one ton of ordinary coal, if no portion of the air is wasted. Double this quantity, or even a larger proportion is frequently supplied. If double the quantity be assumed, this 11 tons of superfluous air must be heated from the combustion of the one ton of coal, and not only greatly reduces the temperature of the furnace, and its evaporative power, but in leaving the boiler at a temperature, it may be 600° or more, higher than it entered the furnace, it thus carries off a large percentage of the heat of the fuel. The loss stated in figures caused by this 11 tons of superfluous air leaving the boiler at 600° above the entering temperature is $11 \times 2240 \times 0.246$ (the specific heat of the escaping gases) $= 6061.4$, which $\times\ 600 = 3{,}638{,}840$, the loss in units of heat, being fully $12\frac{1}{2}$ per cent. of the total heat of combustion of the ton of coal, taking the efficiency of the coal at 12,600 units per lb.

The dilemma, therefore, in which every furnace operator finds himself when working with natural draught, is the choice of admitting either a moderate amount of air to the furnace, and having in consequence an imperfect combustion, with much smoke and considerable waste of fuel, in carbonic oxide passing to the chimney, or of admitting air greatly in excess of what is required for perfect combustion properly effected, and obtaining therefrom a more complete combustion at the cost of a large waste of heat carried off to the chimney by the superfluous air, besides the reduction of the evaporative power of the boiler by the dilution of the furnace temperature. Of these two sources of loss, unfortunately, the greater is generally that arising from the too liberal supply of air, consequently the hotter furnace, with increased steam and much smoke, is preferred by all stokers to the cooler furnace with diminished steam and less smoke. We thus find, unless it is restricted by the most severe penalties, smoke polluting the atmosphere in every place where steam power is used, hanging over our manufacturing towns like a cloud, and marring the most beautiful rural scenery, as well as our finest rivers and estuaries; a nuisance which apparently owes its toleration to its universality.

The imperfections such as enumerated attending the combustion of coal by natural draught, with the limitation of the supply of steam, often further effected by the state of the draught and quality of coal, have led to frequent attempts during the last thirty or forty years to effect combustion in boiler furnaces by air supplied by mechanical means above atmospheric pressure. These repeated attempts, however, have not hitherto been successful, and, therefore, except in locomotives and torpedo boats, supply of air by natural draught is still in universal use for steam boilers. The causes of failure, though various and often not at first sight apparent, become, nevertheless, obvious when sufficiently investigated. A short description of the most prominent of these attempts to improve combustion by mechanical means may be of some interest. The plan which has probably been most frequently tried is that of forcing air by a fan or other blower into a closed ash pit. This mode of increasing the power of a furnace, though apparently simple, must always be disappointing, for the following reasons:—If the coal on the fire-grate be kept sufficiently thin to permit the oxygen of the air supply to penetrate to the upper layers of the fuel to effect combustion of the inflammable gases, the quantity of air passing through will be too great, and the temperature of the furnace will be unnecessarily reduced, and much loss of fuel occur. If, on the other hand, the coal be laid sufficiently thick to prevent an undue quantity of air from passing through, there will be a lack of air to consume the combustible gases generated by the great heat from the combustion of the lower layers of fuel. Much smoke will in consequence be produced, and also carbonic oxide, so that in this case also less economy will follow than may be realized by natural draught. This system of supplying air to a furnace is likewise very severe on the fire bars, and has other disadvantages which time will not permit reference

to. It is now exactly twenty-two years since I constructed a boiler to try this mode of effecting combustion by air under pressure. The boiler was erected in the yard in which it was built. It had a short chimney, and the air was supplied to the closed ash pit by an engine and fan. The results of the trials were disappointing, and exactly of the character I have described. They were not, however, altogether valueless, as they clearly showed that forced combustion could not satisfactorily be carried out on this system.

A second method resorted to for increasing combustion in boiler furnaces is that of exhausting the air in the chimney or uptake by a fan, thus reducing the pressure in the flues or tubes and furnaces, and thereby inducing a more rapid current of air through the furnace both below and above the grate-bars. This plan, so far as the supply of air to the furnace is concerned, is in practice more workable than the plan previously described, as the air enters the furnace not only at a greater velocity than is attainable by natural draught, and is thereby capable of being more thoroughly intermingled with the fuel all over the furnace. but being also balanced in pressure above and below the grate-bars, the operations of the furnace become much more easily managed. This mode of creating these advantageous conditions in the furnace is, however, objectionable. The passing of the hot gases of combustion through a working fan of itself a mistake, practically and theoretically. Even if it were possible for the machine to continue in working order under this ordeal for any length of time, the hot gases, if leaving the boiler at no more than 480° above the entering temperature, would be twice the volume of the air which entered the furnace from the stokehold. A fan to exhaust the hot air would, therefore, require to be at least double the capacity of one which would have supplied the same quantity direct from the stokehold to the furnace. This plan, which is one of the earliest tried, is therefore impracticable for large boilers, and has only been occasionally used in boilers of a limited size.

A third method producing the same effect on the furnace as the last is that of inducing a current by means of a steam jet in the funnel. This plan is simple, requires no working machinery, and is within certain limits effective. It illustrates the advantage of mixing the air more thoroughly with the fuel than is possible by natural draught, as by its use a greater evaporative power is obtained, while the consumption of fuel per horse-power of the engine is not more than the rate per horse-power for natural draught, notwithstanding the loss of steam by the jet. The waste of water by this system unfits it for marine boilers working at high pressure, and it is not required in land boilers with high chimneys. It is, however, seen on a grand scale, and in its most legitimate use, in the locomotive boiler, where, instead of merely a small percentage of the steam from the boiler being used for the purpose of inducing a current through the furnace, the whole of the steam generated is used for this purpose. The remarkable effect of the powerful action of the blast pipe is well known. It has increased the power of the boiler at least six-fold that possible by natural draught. What we owe to this power of increased combustion is simply incalculable. It is not too much to say that the amount of traveling and carriage of goods from end to end of the kingdom could not have reached a tithe of its present enormous extent but for this powerful artificial supply of air to the furnace of the locomotive boiler. An average consumption of 100 lbs. of coal per square foot per hour is burnt on the fire-grate of an express locomotive, and what should not be overlooked in the consideration of this subject of combustion under air pressure, this astonishing rate of combustion is accomplished with comparative ease and remarkable economy.

A further method of improving combustion, and especially of effecting smoke prevention, which has been frequently tried, is that of increasing the supply of air to the fuel above the grate by currents induced by steam jets. The steam jets penetrate the fuel, carrying with them the air to supply the necessary oxygen to parts of the furnace which would not be sufficiently reached by natural draught. Combustion by this means is improved, and smoke in large measure prevented. This is not in itself an economical plan, and it has several objectionable features. For marine boilers it is for various reasons unsuitable. It gives another

proof, however, of the advantages, within limits, of an artificial supply of air above atmospheric pressure, as the better combustion it promotes compensates to a considerable extent for its inherent wastefulness.

The most successful plan, in some respects, that has hitherto been applied to marine boilers is that of the air-pressure stokehold or boiler-room, as used in the torpedo-boats—a system so well known to the members of this institution as to render description unnecessary. The air enters the furnace above and below the fire-bars in the same manner as by natural draught, but at the increased velocity due to the difference of air-pressure in the boiler-room over that of the atmosphere outside. The results obtained in evaporative power approach that of the locomotive boiler. The comparatively small boilers used in these boats, generally of the locomotive type, under the powerful action of the great supply of air to the furnace under pressure, generate steam sufficient to impart a speed of twenty-five or twenty-six miles an hour to the vessel. The success of this system in torpedo-boats has led our own and other governments to apply it to large steamers having a number of boilers with several furnaces in each. It being impracticable to make air-tight a large boiler compartment, and the coal bunkers which must necessarily be in open communication therewith, the plan has been adopted of forming air-tight chambers, or rooms, on the furnace ends of each boiler, or pair of boilers, into which the air is forced by fans working on the deck above. These rooms contain the coals being used by the stokers on duty. Access to the chambers is obtained by doors designed to prevent egress of air. At the meetings of the institution last year a most interesting paper was read by Mr. R. J. Butler, giving much valuable information regarding the application of this system to H. M. steamships *Satellite* and *Conqueror*. The results of the trials in these steamers show that much larger supplies of steam can be obtained by this system with less discomfort to the stokers than would have been possible from natural draught.

This statement appears, however, to exhaust all that can be said in favor of this system. Its practical disadvantages are very considerable, even in war vessels, and are more than sufficient to prevent its application to mercantile steamers. The chief defects of the system—and they are serious defects—are its wastefulness and its tendency to injure the boilers. It is a system which may be characterized as one for obtaining an increase of power regardless of expense. After experiencing the impossibility of working a furnace with air under pressure without waste of fuel, unless most carefully studied precautions are adopted, I can state without hesitation that the indiscriminate admission of air in this system must be wasteful of fuel in a very high degree. The effect on the boilers themselves, whenever a furnace door is opened, of the rush at full pressure of a column of cold air, equal to the area of the furnace door, at a velocity from 80 feet to 100 feet per second, must be most injurious. The furnace plates, as well as the tube and other plates of the combustion chamber, cannot but suffer severely, while the great volume of cold air lowers the temperature of the whole boiler, and greatly neutralizes the benefit of the rapid combustion of fuel. Mr. Butler did not state in his paper the consumption of coal per horse-power developed by the engines when at their highest power, but indicated that when the power was much increased beyond that obtainable by natural draught, the expenditure rose largely out of proportion to the increase of power.

Mr. Butler also stated that in the *Satellite*, after a few trials, each of several hours' duration only, "a number of the boiler tubes were leaky," and in the *Conqueror*, after similar trials, that "both seams and tube-plates were leaking," and expresses the opinion in regard to the endurance of the boiler, "that the frequent use of the forced draught would produce a great diminution in the life of those parts subjected to the intense heat." From experience in working boilers on a large scale in a similar manner, that is, with sudden alterations of heating and cooling, I can fully endorse Mr. Butler's opinion regarding the short life of the boilers, attributing, however, the injury to the boilers not to the intense heat, but to the sudden changes of temperature. From the fact that the indications of injury in the boilers of the *Satellite* and *Conqueror* were not greater, I would in-

fer that the water used was fresh, or, at least, that the plates were entirely free from scale when the trials were made. When scale is formed on the plates to any extent, the injury from this mode of working becomes very marked. Altogether, it appears to me that this system of increasing combustion is, from its wastefulness and the defects I have mentioned, unsuitable for continuous working in any large steamer. For torpedo boats with one furnace, where the disadvantages are minimized, this system may hold its place, and as these boats are only occasionally used, waste of fuel is, therefore, in them of small importance.

I now come to describe a system of increasing combustion artificially, which I devised during the year 1880, having been led to this arrangement by the remembrance of the causes of failure to obtain satisfactory results in 1862, already alluded to, and also by observing the defects of the different methods to which I have referred. In the summer of 1882 I had an opportunity of applying it to a small marine boiler, 7 feet diameter by 7 feet 9 inches in length, having two furnaces each of two feet diameter. The results being satisfactory, I constructed a boiler for the purpose of testing on a sufficiently large scale the various important advantages contemplated by the adoption of this mode of working. This boiler is 10 feet in diameter by 9 feet in length, with two furnaces, each 3 feet inside diameter. The furnace tubes extend the whole length of the boiler, the fire gases returning to the front from a dry chamber at the back end lined with fire-brick and otherwise protected from radiation of heat, through two separate stacks of tubes, each stack having 45 tubes, $3\frac{1}{4}$ inches external diameter. This boiler I erected in a yard by itself in July last, with evaporating tank, engine and fan, and other appliances suitable for testing results, and have since then been engaged more or less frequently in making trials under various conditions. The principal ends which I have endeavored to accomplish satisfactorily are:—

(1.) To effect with ease and certainty complete combustion of fuel in the furnaces of ordinary steam boilers at all rates from zero up to that of a locomotive boiler if required.

(2.) To effect this combustion at all rates, whether high or low, economically as regards fuel.

(3.) To effect this economical combustion rapidly or slowly in boilers of ordinary character, either singly or in numbers, without any change in the usual conditions of stokeholds for boilers worked by natural draught.

(4.) To effect the foregoing purposes with less discomfort to the stokers and attendants, and with less wear and tear of the boilers and furnace fittings, than is experienced when working in the ordinary way with natural daught.

To attain the ends sought for under the first head made it necessary to use air under a pressure above the atmosphere, such as is conveniently got from a fan, with simple means of using more or less of this air as required. To attain the second point, that of economical combustion at all rates, it was imperative that the supply of air should not only be under perfect control, but that the necessarily varied quantities admitted per unit of time or of coals consumed, should be exactly ascertained; and, further, its distribution should be as nearly as possible equal over the furnace, and limited as nearly as possible to the theoretical quantity for the weight of fuel being consumed; finally, that the waste of the heat of combustion should be reduced to a minimum. To accomplish the third, it was necessary that the supply of air to any single furnace in a boiler, or to any boiler in a series, should be quite independent of the supply to the other furnaces or boilers. The advantages under the fourth head follow from the more economical combustion requiring less supply of fuel than would be necessary with natural draught, by the radiation of heat into the stokehold from the furnaces being prevented, and by the supply of air to the fan being made to circulate through the stokehold. The saving of tear and wear is due to the air being introduced to the furnace so as to preserve the furnace fronts and interior fittings, and also to the prevention of the usual injurious rush of cold air into the furnace when stoking, by suspending the air admission when a furnace door is open.

The manner in which I have endeavored to carry out these several purposes will be understood more clearly by the following description: On the front end of the boiler an air-tight chamber or res-

ervoir is formed of light plate iron, to receive the air for combustion under pressure from a fan. This air chamber extends over the whole front of the boiler, from some distance above the upper row of tubes downwards, so as to enclose the furnaces and ash pits. The smoke-boxes of each stack of tubes are completely separated from the air chamber by suitable castings, as are also the furnaces and ash-pits, so that no air can enter the furnaces or ash-pits except through passages regulated from the outside by valves. The upper portion of the reservoir extends outwards from the boiler not more than the ordinary smoke-boxes and uptake; below, at the furnaces, the reservoir in this case extends 7½ inches from the boiler, but this may be reduced. On the front of the castings which separate the furnaces from the air chamber, the outer furnace doors and ash-pit doors are hinged air-tight. Attached to the outer furnace doors by studs, and moving on the same hinges, are the inner and proper doors of the furnaces, which shut on the inner front plate in the usual manner. A dead plate between the outer and inner front plates separates the ash-pits from the furnaces above the fire bars. Into these spaces above the dead plate and between the outer and inner furnace doors the air is admitted in the desired quantity from the common chamber by simple plate valves, and after passing through perforations in the doors, at the sides, and above the doors, is received into cast iron boxes, which serve the double purpose of protecting the front plate and furnace door from the great heat, and distributing the air effectively among the fuel. The air is admitted as required to the ash-pits by separate valves.

By these arrangements the admission of the air to different parts of the furnace is kept under perfect control, the quantities admitted being ascertainable, and all radiation of heat from the furnaces or ash-pits prevented. The heat of the fire gases after they leave the boiler is largely utilized by causing them to pass up through the tubes in the air reservoir immediately above the smoke boxes, as shown. While the hot gases pass through the inside of these tubes, the cold air from the fan entering by the pipe is made to sweep right and left among the tubes, carrying a considerable portion of the escaping heat downwards by the sides of the smoke boxes to the furnaces. When a furnace or ash-pit door is opened for stoking purposes, the air admission valves for that furnace are closed, so that the furnace may be operated on in a quiescent state. No rush of cold air can thus pass into the furnace, as in the air pressure stokehold system, or even as in boilers worked by natural draught. The saving of the boiler from injury, and the prevention of waste of fuel, by this means are important features. When it is desired to reduce or increase the rate of combustion, the admission valves are opened or shut as required, and with any given pressure of air in the chamber, it is not difficult, after a few trials, to establish the required openings for different rates of combustion, from zero to the highest rate possible by the given air pressure. When the admission valves are entirely shut the combustion may be practically suspended for hours, the fires continuing more or less incandescent. By this means a steamer may with ease be kept lying under any desired pressure of steam for any length of time, and without tendency to blow off.

In erecting the boiler for trial, I purposely made the conditions under which it was to work as difficult in regard to combustion as would ever be likely to occur under the most unusual circumstances in actual practice. The funnel was made only 15 inches in diameter and 21 feet high from the fire grate. A still greater restriction was the limiting of the air heating tubes in the reservoir (through which the whole of the fire gases issuing from each furnace have to pass to the common uptake) to fourteen in number of 3½ inches external diameter. The effect of these restrictions and contractions is to reduce largely the rate of combustion with a given pressure of air. With natural draught this boiler, as described, generates steam very slowly. With 2 inches to 2¼ inches of air pressure a combustion of about 30 lbs. per hour per square foot of fire-grate can be reached. This rate could evidently be doubled with a corresponding increase in outlet area, or by increasing the air pressure, but the latter would be undesirable where the former can be accomplished. Under the restricted conditions described, the boiler

is worked with the utmost ease at any rate of combustion up to the limit mentioned, and with absolute freedom from smoke. In the numerous trials which have been made during the last seven months I have endeavored to ascertain the following particulars :—

(1.) The rates of combustion effected by admissions of air varying both in quantity and pressure.

(2.) The effect of different quantities and velocities of air admission on evaporative economy.

(3.) The most favorable modes and proportions of admission and distribution of air under different pressures.

(4.) The nearest approach to perfect combustion chemically at various pressures with the least possible admission of air.

It will be evident that the elucidation of these various particulars with tolerable accuracy requires a great number of trials, and as each trial is frequently of five or six hours' duration to ensure accuracy, a great expenditure of time is involved. Though the trials have been going on for the time mentioned at about an average of one per week, they are not yet so complete as to enable me to establish definitely the best proportions and velocities of air admissions above and below the fire-grate for all rates of combustion. I can as yet only give approximations, though the conditions which yield the most favorable results are more or less ascertained. As I mean to continue these trials, I hope to be able to give fairly complete statements on some future occasion. At present the time at my disposal will only allow of a few remarks describing the mode in which the trials have been carried out. In ascertaining the effect of the admission of air above as well as under the fire-grate, trial was made with different areas of apertures, and of different pressures of air on equal areas. For example the trials were begun with a limited aggregate area in the holes of the air-boxes inside the furnace, this area being gradually increased until it was found that the increased area added little to the rate of combustion, while the evaporative economy became sensibly reduced. The admission below the grate was also tried with various areas of air inlet apertures and pressures, and their effect noted on the combustion and evaporation.

In the course of these trials some interesting results were noticed. For example, when the air admissions above and below the fire-bars were regulated in certain proportions to each other, if the admission openings above were then decreased, and those below increased to about the same amount, a much higher rate of combustion took place than when the process was reversed by increased admission above and decreased below. This difference arose from the changes produced in the balance of pressure in the furnace. When the pressure is relieved somewhat above and increased below, the air passes much more rapidly through the fuel in its passage to the chimney, with a correspondingly more rapid combustion, than it does if, with the same aggregate admission, the pressure is increased above and decreased below. In this case the current upwards through the fuel is greatly checked, and proportions could be so regulated that the current through the fuel could be nearly prevented by the pressure above. At the same time the admission of air above the fuel in proper proportions serves most important purposes, and contributes towards realizing the highest economy. It has also an important effect in preserving the furnace fittings and fire-bars. I have referred to the great destruction of fire-bars caused by working with the closed ash-pit system. The cause of this destruction became evident to me after I had several trials with the new system I am describing, as in it the admission above the bars tempers the velocity of the air through the fuel from below, while the fuel is kept in perfect combustion above. When the pressure of air is entirely from below, as in the closed ash-pit system, with a sufficient depth of fuel on the grate and a given air pressure, the bars can be melted by the intense heat generated in the lower layers of the fuel. I find, on examination, the fire-bars and air boxes in the boiler I am operating with are still sharp on the corners, and as good now as when put in, after making with them all the trials I have mentioned, and consuming in some cases about 30 lbs. of coal per square foot per hour. This is an important practical result in the working of the furnaces with air under pressure.

The chief point, economically, towards which I have been working in these trials is the attainment of a high rate of combustion with a minimum admission of air,

that is, an admission as near to the theoretical limit as can be practically reached. This is no easy matter, and requires to be worked towards step by step. The trials would have been in great measure a groping in the dark, even with the appliances described, but for the apparatus devised to ascertain by measure of the quantity of air entering at different parts of the furnace above and below the fire-bars at the various pressures used. This device, which occurred to me after several trials were made, is the application of an anemometer, with an apparatus in which the same conditions as to entering and back pressures are created as those which exist in the part of the furnace into which the air is being admitted. The velocity is read off without difficulty, and the dimensions of apertures being known and temperature ascertained, the volume of air is exactly calculable. The system of measurement, combined with chemical analysis of products of combustion, enables one to work with intelligence and certainty. These trials have strikingly shown the great difficulty of obtaining a high rate of combustion with forced blast, without admitting a most wasteful excess of air. It is comparatively easy to obtain a high rate of combustion, but very difficult, unless suitable adaptations are used, to combine a high rate of combustion with economy. In the small boiler, which I first tried with a very complete combustion, the evaporation was very low per lb. of coal, entirely owing to the excess of air. In the present boiler the evaporation has already reached a very fair economy, though not within a considerable amount of what is yet almost certain to be attained.

What has already been accomplished shows that from 9½ to 10 lbs. of water, at 212°, could be evaporated in boilers at sea, from 1 lb of Scotch coal, with a rate of combustion of 30 lbs. per square foot of grate per hour; but there are good grounds for expecting that an evaporation of even 12 lbs. may yet be reached with a rate of combustion from 40 to 50 lbs. per hour per square foot of grate. It should be explained that the boiler I have used for these trials, with the furnace arrangements described, is not intended to represent the best mode of carrying out this system of combustion. It is merely a boiler suitable for ascertaining results under various conditions. There are several changes now being made in the fittings in the light of the results already accomplished, which will, without doubt, increase the evaporative economy without reducing the rate of combustion. Compared with the working of boilers by natural draught, the advantages which this system of combustion by air under pressure gives may be summed up as follows:

(1.) Complete combustion of fuel of all qualities, under conditions in which combustion could not efficiently be obtained by natural draught.

(2.) The power of regulating with ease the amount of combustion desired from zero to many times that possible by natural draught, also the capability of maintaining the fuel in the furnace incandescent for a considerable time without appreciable consumption.

(3.) A great reduction in the size or number of boilers required to produce a given power and the capability of increasing the power in steamships far beyond that now attainable with boilers worked by natural draught.

(4.) Greater economy in producing steam from the following causes—(*a*) From more complete combustion of fuel than is attainable by natural draught with a reduced admission of air. (*b*) From the higher temperature of the furnace arising from the more perfect and higher rate of combustion, and from the air supply being partially heated before entering the furnace. (*c*) From the utilization of the waste heat of the escaping gases. (*d*) From the prevention of heat from the furnaces and ash-pits being radiated into the stokehold. (*e*) From the much less expenditure required to supply the air of combustion from a fan than is required to heat a column of air in a chimney to obtain supply by natural draught. (*f*) From preventing the cooling down of the boiler by a rush of cold air to the furnace when a furnace door is opened.

(5.) Less discomfort in stoking, the stokehold being kept fresh and cool by by the radiation of heat from the furnaces being prevented, and the fan drawing fresh air into it continuously independently of ventilators.

(6.) The complete absence of the great nuisance of smoke in the use of steam power.

(7.) The abolition of all unsightly

chimneys in town and country now necessary for combustion by natural draught.

The economic advantage of supplying the air of combustion by mechanical means, instead of by the rarefying of a column of air in a chimney by heat, as in natural draught, is given in the concluding illustration. I close this paper by giving an example of the reduction which (basing on there sults I have already attained) may with safety be made in the number and dimensions of boilers in large ocean steamships. I take, for comparison tne *Oregon*, the latest of the large high-speed Atlantic liners. The published accounts give the boilers as nine in number, each 16 feet 6 inches diameter, length 18 feet, with eight furnaces, or seventy-two in all, each 3 feet 6 inches in diameter. Fire-grate, 6 feet in length, making a total fire-grate of 1,512 square feet. Proposed indicated horse-power, 12,000; assumed consumption of coal per indicated horse-power per hour, 2.6 lbs. Total consumption per hour being thus 31,200 lbs., or 13.92 tons. I have here assumed the consumption per indicated horse-power at 2.6 lbs. per hour, without inquiry, as there might be reasons for her owners or builders withholding this information. It is well known, however, that the high speeds in these large steamers are only maintained by a considerable sacrifice of economy; and I have, on the authority of the managing owners of another high-speed Atlantic steamer of about same size and power, that 2.6 lbs. does not over-state the rate of consumption in their experience. I am not aware that 12,000 indicated horse-power has been actually attained in this steamer at sea, but if it has, it could only be attained by stoking of the most severe character. The enormous space occupied by these boilers and by the coal bunkers can easily be calculated from the above particulars.

Using data already verified by actual trial, the boilers, which, on the system of combustion I have had the honor to bring before you, would easily supply steam to the engines sufficient to develop 12,000 indicated horse power, would be six in number, 15 feet in diameter, with six furnaces only in each boiler, or thirty-six in all, each 3 feet 9 inches diameter. The fire-grate 4 feet 6 inches long, making an aggregate of 641.25 square feet of grate. The consumption of coal in the engines working from the boilers, I believe I may safely assume as 1.6 lb. per horse-power per hour, seeing there are engines which approach this rate of consumption supplied with steam from boilers worked by natural draft, having a lower evaporative economy. The consumption of coal at this rate is therefore $12,000 \times 1.6 = 19,200$ lbs., being 8.57 tons per hour, or 320 lbs. per minute. In comparing the expenditure incurred in supplying the air for combustion by an engine and fan in the one set of boilers with that incurred by supplying the same by natural draught in the other of these two sets of boilers, I will assume that the air supply to the furnace per lb. of coal consumed is the same in both cases, though the reduction of the air admission is one of the chief objects of my system of mechanical supply. Assuming the air supply to the furnace to be at the very moderate rate of 15 lbs. per lb. of coal consumed, and that the temperature of the escaping gases of the boilers with mechanical supply is 300° less than the escaping gases of the boilers with natural draught, we have now the means of calculating the required expenditure of each form of air supply. This difference in temperature I assume, because it would be realized in practice. One of the essential points in this system of forced combustion is the reduction of the temperature of the escaping gases to a point far lower than would be possible in such boilers worked by natural draught.

Taking first the boiler with natural draught, consuming 31,200 lbs. of coal per hour, or 520 lbs. per minute, we have the weight of air supplied to the furnaces for combustion $520 \times 15 = 7,800$ lbs., to which has to be added the gaseous products of combustion, or the weight of coal less the ash, which, if taken at $7\frac{1}{2}$ per cent, will give $7,800 \times (520\text{-}39) = 8,281$ lbs. as the total weight of gaseous products passing up the chimney per minute, from the combustion of 520 lbs. of coal. With the specific heat of the escaping gases at .246, the total units of heat wasted or expended in obtaining the power of combustion by natural draught beyond that required to supply air by a fan (the temperature of the escaping gases being 300° higher in the former case than in the latter, as explained) are therefore

$8{,}281 \times .246 \times 300 = 611{,}137$ units less the equivalent of the power required for the fan supply. The mechanical equivalent in horse-power of these 611,137 units of heat is $\frac{611{,}137 \times 772}{33{,}000} =$ 14,296 horse-power. This, of course, supposes the total heat converted into work, and expressed in horse-power units. The actual value of this expenditure of heat is correctly stated in the ratio of the economy of the engines and boilers, which, at 2.6 lbs. per indicated horse-power per hour, is very nearly a utilization of one-twelfth of the total heat of combustion of coal of average quality; therefore, $14{,}296 \div 12 = 1{,}191$ is the actual horse-power equivalent of the 300° heat lost in maintaining the temperature of the funnel in the natural draught boilers.

Coming now to the boilers with the mechanical supply of the air of combustion, and consuming 19,200 lbs. of coal per hour, or 320 lbs. per minute, and taking the weight of the air supplied per lb. of coal at 15 lbs., as in the natural draught boilers, we have $320 \times 15 = 4{,}800$ lbs. of air supply required per minute for the combustion of 320 lbs. of coal. The volume required at 60°, or 13 cubic feet, per lb., is, therefore, $4{,}800 \times 13 = 62{,}400$ cubic feet. To supply this volume per minute from three fans, each having discharge orifices 30″ diameter, or 6.25 square feet area, giving a total area of 18.75 square feet, a velocity of 55.46 feet per second is required, as $18.75 \times 60 \times 55.46 = 62{,}400$. The horse-power required to supply this weight of air at this velocity per second is found by the usual formula, $\frac{W.\, v^2.}{2\, g}$ Here $W = \frac{4{,}800}{60}$ or 80 lbs. air per second, and $\frac{80 \times 55.46^2}{64} = 3{,}845$ foot lbs., per second, and $\frac{3{,}845}{550} = 7$ horse-power nearly. This 7 horse-power is the power required to supply the whole air of combustion for 12,000 indicated horse-power, supposing perfect efficiency in the fans, and in the engines that drive them. Assuming 75 per cent. efficiency in the engines, and 50 per cent. in the fans, we have $\frac{7 \times 100}{75} = 9.3'$ and $\frac{9.3' \times 100}{50} = 18.6$ as the gross horse power for supplying the total air of combustion to the furnaces mechanically.

This 18.6 horse-power as against an expenditure equivalent to 1,191 horse-power (required to maintain a temperature in the funnels necessary to give a sufficient supply of air by natural draught to boilers supplying an equal quantity of steam), shows the vastly superior economy of the mechanical supply of air to boilers, if this air is otherwise judiciously used. The reduction in the weight and number of the boilers, of the space occupied in the vessel, and the saving of coal in a vessel of the power of the *Oregon*, and proportionately in other large steamers, by the adoption of the system of combustion I have endeavored to explain, could not fail to effect the commercial character of these large vessels to a very remarkable extent. The considerable increase recently attained in several new large passenger steamers over the highest speeds previously prevailing has only been reached at very great cost. The principal carrying part of the vessels is filled with boilers and coals, and the expenditure in this department in forcing the vessels to their speed is seriously extravagant. To attempt a still higher speed with the present system of natural draught would be commercially ruinous, even if physically possible. The system of combustion in boilers which I have had the honor to bring before you would not only, I believe, permit the highest speed yet attained to be maintained with comparative ease and economy, but would also, I am convinced, allow of still higher speeds being commercially possible.

REPORTS OF ENGINEERING SOCIETIES.

The Institution of Civil Engineers.—The Council have awarded the following premiums in respect of the original communications submitted during the session 1883-84:—

For Papers Read at the Ordinary Meetings.

1—A Watt Medal and a Telford Premium to Sydney Walker Barnaby, Assoc. M. Inst. C.E., for his paper on "Hydraulic Propulsion."

2—A Telford Medal and a Telford Premium to Samuel Bagster Boulton, Assoc. Inst. C.E., for his paper on "The Antiseptic Treatment of Timber."

3—A Telford Medal and a Telford Premium to William Foster, M.A., F.C.S., for his account of "Experiments on the Composition and Destructive Distillation of Coal."

4—A Telford Premium to William Tregarthen Douglass, Assoc. M. Inst. C.E., for his description of "The New Eddystone Lighthouse."

5—A Telford Premium to James Atkinson Longridge,* M. Inst. C.E., for his paper on "Wire Gun Construction."

6—A Telford Premium to William Hackney,† B.Sc., Assoc. M. Inst. C.E., for his paper on "The Adoption of Standard Forms of Test-pieces for Bars and Plates."

7—The Manby Premium to George Henry Stayton, Assoc. M. Inst. C.E., for his paper on "Wood Pavement in the Metropolis."

For Papers Printed in the Proceedings without being Discussed.

1—A Telford Medal and a Telford Premium to Thomas Andrews, Assoc. M. Inst. C.E., F.R.S.E., for his paper on "Galvanic Action between Wrought Iron, Cast Metals, and Various Steels, during Long Exposure in Sea-water."

2—A Telford Medal and a Telford Premium to Francis Collingwood, M. Inst. C.E., for his paper "On Repairing the Cables of the Allegheny Suspension Bridge at Pittsburgh, Pa., U.S.A."

3—A Telford Premium to James Henry Apjohn, M.A., M. Inst. C.E., for his note on "The Area of Sluice-opening necessary for the Supply Sluice of a Tidal Canal."

4—A Telford Premium to Thomas Gillott, M. Inst. C.E., for his paper "On the Basic, Open-hearth, Steel Process."

5—A Telford Premium to James William Wyatt, Assoc. M. Inst C E., for his communication "On the Art of Paper-making by the Machine, as Exemplified in the Manufacture of High-class Writings and Printings."

6—A Telford Premium to William Santo Crimp, Assoc. M. Inst. C.E., for his account of "The Wandle Valley Main Drainage."

For Papers Read at the Supplemental Meetings of Students.

1—The Miller Scholarship to Alfred Richard Sennett.‡ Stud. Inst. C.E., for his paper "On the Electric Light."

2—A Miller Prize to Peter Chalmers Cowan, Stud. Inst. C.E., for his notes on "The New York, West Shore, and Buffalo Railway and the Methods used in its Construction."

3—A Miller Prize to Walter Osmond Rooper, Stud. Inst. C.E., for his account of "Emery Wheels, and Emery-wheel Machinery."

4—A Miller Prize to Richard Moreland (*tertius*), Stud. Inst. C.E., for his paper on "Constructional Ironwork for Buildings."

4—A Miller Prize to Edward Woodrowe Cowan, Stud. Inst. C.E., and a Miller Prize to James Fawcus, Stud. Inst. C.E., for their joint paper descriptive of "A Light-draught Launch."

ENGINEERING NOTES.

A LARGE planing machine in the Charlestown Navy Yard, at Boston, built in 1866-69 by S. Wilmarth, is described by the Boston *Globe* as the largest one in the world. "Its total weight is 300 tons; extreme length, 55 ft.; width, 31 ft.; height, 29 ft. It will plane a piece of metal 18 ft. square and 45 ft. long. It will also plane at right angles or vertically. It will plane a piece weighing 200 tons if required at any given angle, and is capable of boring, turning, slotting, or splining to a depth of 4 ft. and at any taper indicated. The lightest class of work is accomplished with great rapidity and accuracy. Among other specialties it will bore, turn, and cut gear wheels of any required size up to 40 ft. in diameter. It will bore and spline propellers of any size and weight."

THE WATER SUPPLY OF VENICE.—Those who have stayed in Venice have learned what it means to be dependent for water upon an army of men, who with barges fetch a daily, or rather nightly, supply of liquid, rarely fit to drink, across the lagoons from a stream emptying near a place called, if we remember correctly, Servola. These old travelers, and those who have yet to visit that much-visited city, will be glad to learn that the inauguration of the Venice Waterworks, by which a real piped-water supply is carried into the romantic city, took place on the 23d of June last, and fully realized the expectations of all concerned in this piece of hydraulic engineering, which is internationally interesting. The contract for the works has been carried out by the Public Works' Company of Italy—Messrs. Breda & Co. including the construction of the reservoir and filter beds at Moranzano on the mainland, and the laying of the pipes under the Laguna to the city of Venice of a total length of 6,460 meters, of a diameter of 80 centimeters—31. 5 in.—and the laying of the total length of mains in the thoroughfares and canals of 25,706 meters of a diameter of 30 centimeters—11. 8 in. In the course of laying these mains they were taken at eighty-five places across canals, and twice across the Grand Canal, work which involved considerable difficulties. The work also included the construction of an engine house and reservoir at St. Andrea, the erection of a pair of 50 nominal horse-power engines, together with laying on the water to all the principal buildings and hotels in the city. The work was commenced early in January, 1881, and was consigned to the entire satisfaction of the concessionaires on the 23d of June, 1884. The concession was originally granted to Mr. D. C. Dalgairns, C.E., of Palermo and Penge, in 1876, upon provisional plans and studies then deposited, and the works have been carried out on the definitive plans presented by him on the 23d of June, 1877. The company to which the property now belongs is the Sociétié des Eaux pour les Etrangers, of Paris, which was formed for the purpose of carrying out this scheme in January, 1879. Probably no city in the world had more urgent reason to obtain and maintain an excellent water supply than Venice. Venice lives upon the pleasures of all the nations of the world, and she could not afford that the fearfully bad supply upon which she has depended from time immemorial should drive away even a few hundreds of the many thousands of her visitors. She has therefore gone to the Brenta for water, and now her visitors may at any time, instead of occasionally, have a glass of water to drink, or may even have a bath. Count Dante Serego degli Allighieri, the Sindaco of Venice—a descendant of Dante—through the medium of G. G. Maranzoni, of Venice, has

expressed his deep sense of gratitude to Mr Dalgairns on the successful inauguration, and adds, "The city of Venice is truly alive as to its indebtedness."—*Engineer*.

IRON AND STEEL NOTES.

R. F. Mushet on Blowholes in Steel and Cast Iron.—The creators of the age of steel have ransacked creation to find methods of preventing or lessening, or altogether stopping, these blowholes, with more or less success, but with a great deal more of failure. As Mr. W. H. Fryer has justly observed, these cells are formed or inflated by hydrogen gas. Take away now that gas, and you will take away the cells; but as long as blast furnaces and Bessemer converters are blown with damp atmospheric air, the hydrogen and the blowholes will more or less be there. Why not dry the air, and try the matter fairly? The drying can be cheaply effected for, I suppose, 3d. or 4d. per ton of metal; but nobody appears to have tried the process yet, although it has been before the public, I think, for over two years. It is true that under the withering blight of that enormous sham called "free trade" iron and steel makers have so much to do to hold their own, and to grind down workmen's wages to the lowest point, that they have not time or money to spare to pay attention to improvements, however valuable and useful they may be. The dry blast, however, is well worthy of a fair trial, both in the blast-furnace and in the Bessemer converter. Iron and steel can only get their hydrogen from the blast, and if that blast is desiccated, no hydrogen can be present to form cells. To take pig-iron made—as all of it is at present—with damp blast, and blow it in a Bessemer converter with dry blast, would not be conclusive, for both the blast-furnace and the converter should be blown with dry air, so that no hydrogen could possibly be present.

I have said that the drying is inexpensive, say 3d. per ton; but I had forgotten for a moment that even one penny per ton is a serious amount under our free trade prosperity, which is eating like a cancer into every manufacture, cutting down profits to zero, and, therefore, annihilating capital and wage-paying power. There is a ludicrous phrase, dear to the soul of the Cobdenite. "Holding their own" is their panacea. If anyone can hold their own, that is, just struggle on, short of a composition or bankruptcy, the Cobdenites record it with pleasure. Formerly, employers of labor looked for profits; now, if they can "hold their own," they must be content. The very colliers are not safe from the devouring maw of free trade, for coal is being imported! Even the poor colliers have to hold their own, if they can. When will the petrified fossillized generation of Cobdenites pass away, and so give home industries a chance to thrive once more? Free trade has desiccated home industries, and given the bread of the British workmen to foreigners.

To Tell Iron from Steel, in Small Pieces.—A new fracture ordinarily furnishes the means for classifying test pieces, but its appearance is not a sufficiently safe guide in dealing with good, fine-grained iron or very soft steel. In order to effect the separation with ease and certainty in such cases, Walrand has given a simple method in the *Memoires de la Societé des Ingenieurs Civils*, 1883, page 531. It is by observing the fracture of the test piece after heating and allowing it to take a blue color. The trial can be conducted in the following manner. Take a test piece about twenty-five or thirty centimeters long and make a slight scratch about four or five centimeters from the end. Then heat one end slowly and uniformly to a dark red color (325° to 400° C.) and cool it in water. During the cooling, while the piece is still warm, it must be rubbed with a file from time to time, until the shining metallic surface laid bare, has assumed a dark yellow, or better, blue color, when it is to be cooled quickly and completely. The fractures of the piece broken at the mark serve for comparison. Ordinary wrought-iron broken when cold appears fibrous or crystalline; but, treated as above, its fracture is dull, irregular, and of short fibre. Hard and moderately hard steel are fine grained; after the heating and subsequent treatment, they have a shining, totally or partially, smooth fracture. Swedish iron has only traces of fibers and is hardly to be told from soft steel; after treatment the fibers become distinct, the smooth appearance is lost, and the iron becomes so much the more distinguishable from soft steel treated in the same manner.—*Dingler's Polytechnisches Journal.*

Tests of Iron and Steel Girders.—Some very accurately conducted experiments were recently made by the Dutch government to test the relative strength of iron and steel girders. Hard and soft steel girders were put in comparison with iron girders of a good quality. The tests were made by specimens of the materials from which the girders were made, and also by actual finished girders. Each of the steel girders showed a large increase in strength over the iron girder. The soft steel girders proved 22 per cent. stronger, and the hard steel girders as much as 66 per cent. stronger. The greater strength of the soft steel over the iron in the specimens submitted was fully attained, and even exceeded, in the girders. The hard steel girders did not show so large a percentage of greater strength over the iron girder as did this material in the specimen over the iron in the specimen. This, however, may be accounted for as the result of punching the rivet holes without reaming, for a girder with punched holes gave way during the trials by a fracture of the tension flange, whereas a girder with reamed holes gave way in the compression flange, and probably would have stood more before fracture had taken place in the tension flange. The latter girder did not appear to bear truly upon its supports, and it was prabably this which caused it to fail in the top flange when it did. Punching rivet holes without reaming did not produce any results other than an apparent loss of strength, as compared with reamed holes. The trial pretty well established that the strength of steel girders, strained as these were, is about the same for the two flanges if they are made alike in section.—*Iron.*

RAILWAY NOTES.

It is stated on official authority that there are now 3,000 miles of railway in operation in Brazil. There is scarcely a province bordering on the ocean that has not one or more railways, and all lead to the west, or toward the interior. In the most southerly province, Rio Grande do Sul, the Porto Alegre Railway, now open 91 miles to Cachœira, is being built by the State, and partly for strategic purposes. Steady increase has been lately made in extending several lines; new lines have also been commenced, and there is reason to suppose that the development will annually increase, though the broken surface of Brazil generally, and especially the mountains near the sea-coast, are great obstacles to the rapid development of railway construction. None of the railways have yet penetrated to the vicinity of wild or public lands. Some of them traverse extensive areas of uncultivated land, but as yet no grants of land have been made in aid of railways. The Brazilian Government, however, has extensively guaranteed the payment of interest on railway capital. Its annual burden for the payment of such interest amounts now to a very large sum. The rails for all the lines have to be imported, and the greater part are purchased in England. Many of the locomotives are imported from the United States. It may be also mentioned that several American civil engineers have gained distinction by their services in Brazil, but the field now appears to be occupied by native talent. At the same time, several English railway companies naturally employ English engineers.—*Engineer.*

A Great Railroad event in South America.—A great event in Buenos Ayres has been the recent completion of the Andine Railway to Mendoza, capital of the province of that name, and lying at the foot of the Andes. The importance of this event cannot be exaggerated; the line, it may be said, crosses the continent, stretching from the Parana to the Cordillera. A zone of immense natural wealth is thus thrown open by this quick means of communication, and the traffic on the line promises to be very large. Mendoza is one of the richest provinces of the republic; it covers an area of about 5,000 square leagues of land at the foot of the Andes, with a population estimated at 150,000 souls. The rivers Mendoza, Tunuyan, Desaguadero, Diamante, and Atuel irrigate over 1,000 square leagues of land, and the soil is so bountiful that the yield is often a hundredfold. A very active trade is carried on in the export of fat cattle to Chili, but the great industry of the present and future is viniculture. The Mendoza wines are well known; the production is doubling every two years. The great drawback of the past—onerous and difficult means of communication—is now removed, and the development of all the industries of the province may be looked forward to. The mineral wealth of the province is said to be beyond calculation. —*Iron.*

Railway Accidents.—A blue book has been issued, giving returns of accidents and casualties as reported to the Board of Trade by the several railway companies in the United Kingdom during the first three months of the present year, together with reports of the inspecting officers of the railway department to the Board of Trade upon certain accidents which were enquired into. Among the accidents reported were 10 collisions between passenger trains or parts of passenger trains, by which 120 passengers and four servants were injured; 14 collisions between passenger trains and goods or mineral trains, by which 13 passengers and four servants were injured; nine collisions between goods trains or parts of goods trains, by which two servants were killed and seven injured; 16 cases of passenger trains or parts of passenger trains leaving the rails, by which two servants were killed and four passengers and four servants injured; and 32 cases of trains running over cattle or other obstructions on the line, involving injury to four passengers. The total number of persons killed on railways in the United Kingdom in the course of public traffic during the past three months was 254. The injured numbered 990. This is a decrease as compared with the corresponding period in 1883.—*Engineer.*

ORDNANCE AND NAVAL.

Compound Armor Plates.—The Danish Government, following the example set by England, France, Italy, and other maritime powers, has decided in favor of the adoption of English compound armor plates, as superior to all others for the protection of ships against modern rifled ordnance. This was only to be expected. It would, indeed, have been surprising to find a government such as that of Denmark arriving at any other conclusion, after the experience gained at the trials which have been made throughout the world of iron, steel, and compound armor plates. The latter have invariably proved superior to all other means of protecting a ship's side, and, although it was at one time thought that the influence in Copenhagen of the French Creuzot works was powerful enough to influence the Danish government to use solid steel plates to protect their ships, the final decision arrived at last week shows that the Danes are determined to use the very best material they can procure, irrespective of its nationality. It will be remembered that at the last trials on the island of Amager, near Copenhagen, both the Ellis and Wilson systems of facing iron plates with steel were tried. The Danes have now decided to adopt the latter system, as being, in their opinion, superior to the former. It has come to be admitted by all naval powers that compound armor is far better able to withstand the heavy blow of the projectile thrown by modern ordnance than are either solid steel or iron plates; and, since steel-faced plates are solely made in Sheffield, this English industry will be busy for many years to come. Russia, however, is alive to the advantages of producing at home all the material required for its navy; and Messrs. Cammell & Co. have recently received an order from the Russian government to forthwith set up works within its frontiers for the manufacture of Wilson's compound armor plates. The armor for the French ships Duguesclin, Vauban, Requin,

Caiman, Admiral Baudin, Dupere, Furieux, and Tonnerre, is being made in France on the Wilson system. That of the Indomitable was manufactured in Sheffield by Messrs. Cammell & Co.; as were also the plates for the Russian Vladimir Monomach, the Chinese Chen-Yuen, the Braziliac Riachuelo, the Italian Italia, and many other modern ships of foreign governments. Our Admiralty use both Wilson and Ellis compound plates, it not being deemed expedient, where so many ships are constantly in course of construction, for the government to be solely dependent on one firm.—*Army and Navy Gazette.*

Machine Guns in the Field.—At the meeting of the Royal United Service Institution, held on July 4, Capt. Lord Charles Beresford, R.N., read a paper on the above subject. There were several specimens of those weapons on the floor of the theatre—a Gatling, with ten barrels, worked by means of a crank; a two-barreled Gardner, and a couple of Nordenfelts, one of them mounted on a carriage complete.

Lord Charles Beresford said that, as a naval officer, he had a certain amount of hesitation in taking up a question which officers of the army might naturally think belonged peculiarly to themselves. At the same time, it must be remembered that the navy had had more actual experience in the working of machine guns in the field than any other portion of Her Majesty's service, and guns for this purpose were supplied to the navy, but not to the army. A machine gun proper was a gun without recoil, or, in other words, was a weapon which did not require re-laying after every shot There were two entirely distinct kinds of such guns; the one a shell-firing gun, and the other a bullet-firing, or rifle-caliber, gun. International law did not admit of any explosive projectile under 14 ounces in weight, and the weight of a machine gun throwing such a projectile would detract from its value as a machine gun, and would make it almost artillery. Dealing wlth the small-bore caliber gun, to which he should confine himself, Lord C. Beresford discussed the recent trials at Poona of a ten-barreled Nordenfelt, and showed that the results were equal to the fire of seventy men with rifles, and 80 per cent. better than the hits from four 7-pounder mountain guns. He pointed out the value of the guns to the landing party at Alexandria in 1882, and proceeded to demonstrate the value of the weapon to artillery, cavalry, or infantry. He quoted the words of eminent military men in all branches of the service, giving some cases where guns had been of value, and others where days would have been saved and reputations upheld by the presence of a couple of machine guns. An instance was at Maiwand, where, he said, if there had been any machine guns the guns would never have been lost, the cavalry would never have been kept so many hours inactive under a heavy fire, and the day would have been saved. He described the machine guns mounted on galloping carriages, and mentioned a few engagements in which the English troops had been fighting where a machine gun mounted as described would have been of infinite service. He urged that it would be better to do away with the limber altogether, and commented severely upon the disaster likely to result from a mixture of ammunition, quoting an instance where a box of Gatling ammunition got mixed with the ordinary ammunition, and where if the men had attempted to use the cartridges, the result would have been that every rifle would have been virtually spiked, as the discharged cartridges could be got out only with great difficulty. In conclusion, Lord Charles Beresford said that the machine guns of the present day are accurate, rapid in their fire, and terrible in their man-killing power is beyond doubt; whether they can or cannot be better utilized for the services is a grave question for consideration. For volunteers they would appear to be admirably adapted, and the London corps under Colonel Alt have lately demonstated (as far as drill can do, and in the recent sham fight at Portsmouth) how exceedingly useful they might be. Artillery officers, as a rule, are supposed not to look upon them with favor, but most of the arguments used against them appear to treat them as guns instead of clusters of rifles, which they really are. In the course of a discussion which followed, Admiral Boyes expressed the opinion that it was a *sine qua non* that the ammunition for machine guns should be the same as for guns used in the field. Captain Colomb remarked that the navy, to a man, considered that the age of the machine gun was just commencing. Major Lewis referred to instances where single-barreled machine guns would be most useful. Other officers also took part in the discussion.

BOOK NOTICES.

Publications Received.

Temperature of the Atmosphere at the Earth's Surface. By Prof. William Ferrel. Washington: Government Printing Office.

L' Assainissement Suivant le Systême Waring. Paris: Baudry et Cie.

Papers of the Institution of Civil Engineers:

No. 1927. The Canadian Pacific Railway. By J. C. James and Allan Macdougall.

No. 1988. The Alleghany Suspension Bridge. By Francis Collingwood, M. Inst. C.E.

No. 1966. Wandle Valley Main Drainage. By William Santo Crimp, Asso. M. Inst. C.E.

No. 1958. Wire-Gun Construction. By James Atkinson Longridge, M. Inst. C.E.

No. 1968. Hydraulic Propulsion. By Sidney Walker Barnaby, Asso. M. Inst. C.E.

Proceedings of the Engineers' Club of Philadelphia.

Forestry in Norway. Compiled by John Croumbie Brown, LL.D. London; Simpkin, Marshall & Co.

The student of Physical Geography will find much to interest and to instruct in this little volume. All the conditions of climate and soil that influence the growth of vegetation are fully discussed.

How completely the physiography of Norway is presented, may be inferred from the following list of chapter headings; General features of the country; Forest Scenes; Mountain Plateaux; Distribution of trees in Norway; Con-

ditions upon which distribution depends; Conditions of distribution in Norway; Temperature; Rainfall; Rivers; Lakes; Winds; Geological Formations: Mountains and Fields; Snow fields and Glaciers; Mechanical action of Glaciers: Saeter life; Valleys, Forest Exploitation, and the Timber Trade; Shipbuilding and Shipping; Forest Devastation: Remedial Measures.

This is one of the lesser contributions to the literature of Forestry from the pen of this industrious writer, but it will be widely read for the information it affords on other topics.

GUIDE DER NIVELEUR. Par J. VERRINE. Paris: Paul Dupont.

The different methods of leveling, from the rudest to the most finished, are elaborately described in this little book.

The instruments are classified as of three kinds, the builder's level and the old water level representing the first class; the pendulum level and the reflecting level, the second class, and the engineer's telescope level the third class.

Two full chapters are devoted to the different forms of rod and the errors to which they may respectively give rise.

Section and cross-section work with notes, profiles and graphic solutions of earthwork problems form the matter of the four conclusive chapters.

Nearly two hundred illustrations are interspersed throughout the text.

A TREATISE ON PRACTICAL MINE VENTILATION. By EUGENE B. WILSON. New York; John Wiley & Sons.

The author of this little treatise explains in his preface that he "has endeavored to deal with ventilation in such a manner that no one with a fair knowledge of the English language and of arithmetic need despair of thoroughly mastering it.

"Knowing that the miner possesses but a comparatively small stock of words, and is not an adept in algebraic formulas, the writer has taken a different position from the standard works on the subject, endeavoring to do away with abstruse language, and such highly mathematical formulas as are only calculated for well educated engineers."

The omission of abstruse language has been fairly well observed, but in some instances at a large expense of accuracy. For example, the author says of oxygen, "It devours everything with which it can unite; it corrodes metals, decays fruits, promotes combustion, and is a prime necessity for health.

"The body is a stove in which fuel is burned; the chemical action being the same as in any other stove."

Again on page 25 occurs the following; "The 'motive column' is a 'head of air" of such a height that it will equal the difference between the weight of the downcast and upcast columns of air."

This is followed by an incorrect formula:

$$M = D \times \frac{t - t_1}{459t + t_1}$$

The explanation is furthermore afforded that —"The relative diameters of the shafts make no difference upon the total pressure, so far as the considerations regarding ventilation are concerned. This is termed the 'pneumatic paradox.'"

All that is not abstruseness in this last paragraph is misinformation. It should, however, be stated in justice to the author that the illustrated examples serve in most cases to set the reader right, and would prevent the learner, if he followed the arithmetical examples, from serious practical mistakes.

A faulty definition, however, may lead the student astray to his future disadvantage. Such an one appears on page 47:

"Coefficient of friction is a term used to represent the constant resistance met with by air during its journey through the mine."

The typography and the arrangement of the formulas are exceedingly good.

SORGHUM: ITS CULTURE AND MANUFACTURE, ECONOMICALLY CONSIDERED AS A SOURCE OF SUGAR, SYRUP AND FODDER. By PETER COLLIER, Ph. D. 8vo, cloth, Cincinnati, R. Clarke & Co.

The development of an important industry is an achievement deserving of great honor, and so when an American chemist establishes on a solid basis a new American industry, unqualified praise is due to him.

In 1877, at the request of the head of the Agricultural Department at Washington, D. C., Professor Collier undertook the examination of Sorghum and maize as sugar-producing plants. Since that time much of his ability and energy has been devoted towards the practical solution of these questions, with special reference to Sorghum. The different annual reports of the chemist give the results of careful investigation and show a steady progress in his work. Experiments were made for the purpose of determining the best varieties of the plant for cultivation, the conditions of soil, the effect of fertilizers, the most suitable forms of machinery. These and other like topics came up for consideration and were successively studied. Before long, factories were established at various localities throughout the country. Certain of these were unsuccessful while others flourished until, in 1882, the statistics given in the annual report of the Agricultural department for that year show a production of 510,780 lbs. of sorghum sugar. In 1883, upwards of 850,000 lbs. were reported, and to-day probably more than 1,000,000 lbs. are being manufactured. According to the census returns of 1880 the production of sorghum syrup is given as 28,444,202 gals., while in 1860 only 6,749,123 gals. were obtained. Such, in brief, is the history of the development of sorghum sugar industry.

In the book before us, we find arranged in the most admirable order, a discriminating and judicious selection from the information which Prof. Collier has accumulated from his experience and researches. In his own words it includes "the most important facts relating to the economic production of sugar, syrup, and fodder from sorghum." As an authority on this subject, the author stands second to none. He is an enthusiast, and as he is conscious of the truth of his statements, conviction that he is right will follow from a perusal of them.

Prof. Collier has done much to benefit his fellow citizens, he has also suffered severely from adverse criticism. It will be the mission of this book to widen and extend his influence, to increase his reputation, and to bring about a full realization of his most sanguine hopes for the sorghum industry.

TEXT-BOOK OF DESCRIPTIVE MINERALOGY. By HILARY BAUERMAN, F. G. S. London: Longmans & Co.

We have here a descriptive treatise on mineralogy, though only the more important species, scientifically or economically speaking, are decribed in detail.

The subject of nomenclature is considered at some length. The author remarks that "names founded on physical or chemical peculiarities are, as a rule, among the most uncouth and inconvenient, and as they are not unfrequently founded upon false analogies, some trivial character, or one that may be common to many other minerals being selected as a specific distinction, a knowledge of their etymology is not always of advantage as an aid to the memory." Mr. Bauerman holds, very judiciously, that in the case of minerals worked as ores the ordinary commercial names should always be used where possible. "Thus for all purposes copper-pyrites, tinstone, and zinc-blende are preferable to calkopyrite, cassiterite, and sphalerite."

The author's classification is substantially the same as that followed in the second edition of Rammelsberg's work. The statements of localities are generally on a level with the most recent discoveries. The only mineral of commercial importance which we miss is bauxite, which certainly does not figure in the index. The illustrations, being printed from the blocks used in Brooke & Miller's work, are excellent, and contribute greatly to the value of the work. *Chemical News.*

STEAM AND MACHINERY MANAGEMENT. By M. POWLS BALE, M.I.M.E., Assoc. M.I.C.E. London: Crosby, Lockwood & Co., 1884.

This work forms one of Weale's Rudimentary Series published by Messrs Lockwood & Co.—Owing to the great and increasing competition of the present day in every branch of manufacture, it cannot be denied that it becomes increasingly necessary to exercise every economy that will either lessen the cost of production or increase the efficiency of the plant employed. It must be admitted that a considerable loss often arises through inefficiently managed or badly arranged machinery; and this subject is now attracting a considerable amount of attention, with the result that many old manufactories have been remodeled and new ones built and arranged with appliances to reduce manual labor and the cost of production to the lowest possible limit. As a portion of the matter contained in the author's recently published work, *Sawmills: their Arrangement and Management*, would, with modifications and by the addition of other chapters, be made more or less available to general machinery users, and be issued at a less cost than that work, he has with this object in view especially written some fifty pages, and issued *Steam and Machinery Management*. The variety of machinery and manufactures being so great, the author has only selected a few kinds; but most of the hints being general, and not arbitrary, they may be modified as circumstances may dictate. What has now been written by the author may be found of some use by those who intend erecting machinery or who have it already in operation.

MISCELLANEOUS.

IN the last paper of the session read by Mr. Stayton, C. E., at the Institution of Civil Engineers, the aggregate length of the streets of London was given as 1,966 miles, of which, excluding 248 miles in course of formation, 1,718 miles are thus maintained by various authorities, namely: Macadam, 573 miles; granite, 280 miles; wood, 53 miles; asphalte, 13½ miles; flints or gravel, 798½ miles. The existing area of wood pavement is 980,533 square yards, and its estimated cost £600,000. Not more than 4.38 per cent. is east of the city or south of the Thames.

AUTOMATIC LIGHTING OF BEACONS.—In America a system of automatic beacon lights has been adopted. Each beacon is furnished with a reservoir of sheet iron, containing gas under a pressure of fifteen atmospheres. The quantity is sufficient to light the beacon for three months; and fresh supplies are periodically delivered by a vessel which conveys the gas from the factory. A clockwork installed in the beacon, turns on, and lights the gas at the hour fixed for this purpose. The experience of several months has served to test this plan and it has proved so far successful. Attendants live on the shore near the beacons, and see if they are working properly.

PROFESSOR G. FORBES has made some observations on a magnetized chronometer watch. The watch went slow several minutes a day. He found the rate to vary with the position of the watch with respect to the cardinal points and also in a vertical plane. He traced the variation of rate to magnetization of the balance spring, the bar and the screws. The fact that it varied with position suggested that a magnetized ship's chronometer might be made which would integrate the course and give a mean course. Messrs. E. Dent & Co. had since fitted a gold spring and a platinum iridium balance to the chronometer, and rendered it non-magnetizable.

A SURVEY of the coal lands of the Canadian North-West has just been made under the directions of the Dominion Geological Survey. Approximate estimates of the quantity of coal underlying a square mile of land in Bow and Belly rivers district give in one case 4,900,000 tons, in two cases 5,000,000, and in another 9,000,000 tons. The coal is, in general, exposed on the surface, and there is consequently little labor necessary to the working of the mines. Though no Government surveys have been made in the surrounding districts, coal-bearing strata are known to extend to the north and west of the parts from which coal is now being taken.

VAN NOSTRAND'S ENGINEERING MAGAZINE.

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THE MISSION OF SCIENCE:

AN ORATION DELIVERED AT THE PHILADELPHIA MEETING (SEPT., 1884) OF THE AMERICAN ASSOCIATION FOR ADVANCEMENT OF SCIENCE.

By Vice-President ROBERT H. THURSTON, Chairman of Section D (Mechanics).

Before taking up the subject which I have selected as a proper one for discussion in a vice-president's address, on this occasion, I desire to give expression to my sense of the great honor which has been conferred upon me in calling me, for a third time, to the chair of vice-president of the American Association for Advancement of Science, and to preside at the sessions of the section. In taking the position to which your too favorable judgment has called me, it is my first and most pleasant duty to thank you for this most unequivocal testimony of the confidence which you repose in me, and to assure you of my earnest desire to do what little my opportunities and my powers may permit toward making your sessions both pleasant and profitable, and toward promoting the prosperity of the great association to which we are proud to belong.

We are especially favored, the present year, in having with us members of our great sister society, the British Association for Advancement of Science, who have come to join us from Montreal, where the meeting of that society has just been held, and where they have taken part in proceedings of no less importance than interest. It is our pleasant duty to tender to these gentlemen a hearty welcome, and to endeavor to make their visit to the "City of Brotherly Love" one that shall leave in their memories so many reminiscences of agreeable acquaintances made, of strong friendships begun, of open handed and open hearted hospitalities, and of profitable and interesting discussions, that they may never forget the cognomen of this noble city. If we shall be able to give them but a suggestion of the pleasure and the profit gained by those of our own number who were so fortunate as to be able to accept their generous and whole-souled greetings at Montreal, we may well be content. We can at least do our best to convince them that the capital of the "Keystone State," the first capital of the United States, is at least as well entitled to the fraternal regard of our British guests as is the beautiful Canadian city from which they are just come.

As time goes on with steady and unvarying sweep toward the eternity of the future, and as our two nations, our one, hardly divided, people, are becoming bound more and more closely by every interest, and by all memories of the past, by all the sympathies that are engendered in the breasts of members of one race and of one great family; and as we are more and more closely tied by the bonds typified by the continually increasing number of the great cables of steel

nerves that stretch across the ocean which now only nominally separates us, and as we find the once seemingly infinite expanse of that ocean narrowed by that most wonderful of the products of the growth of the science and the art of mechanics, the modern steamship, until the weeks of the past have become the days of the present; as we are beginning to realize the fact of the true unity of the human race, and the duty that lies with us to promote, in every one of the thousand ways that men of science, more than all other men, can effectually work, that spirit of self-abnegation and philanthropy, regulated by the principle of intelligent and honorable self-protection, upon which we are beginning to see that we must, and ought to, rely for the amelioration of the countless evils which are to-day a consequence of selfish and unintelligent human actions, this bond becomes strengthened in numberless ways. We fully realize that "in union is strength," and that the fraternal sentiment which we hope that these meetings are effectively promoting may be a very important factor in the solution of a problem—that of the reduction of the sum of evil in the world—which has been earnestly studied by every thinker since the world began. In behalf of the members of this body, I extend the right hand of fellowship to our guests, and bid them heartily welcome to all that we may be able to offer, and to share with them, at this meeting.

Gentlemen of the section and friends who have honored us with your cheering presence. It is just two hundred years since, in deference to the enlightened views of Sir John Cutler, the Chair of Mechanics was founded in the Royal Society of Great Britain. May we not hope that this Section of Mechanics of the American Association for Advancement of Science may prove to be worthy, in its interest, its fruitfulness, and its stimulation of other and greater work, of so grand an anniversary?

THE MISSION OF SCIENCE.

I have selected the subject of my address on this occasion, "The Mission of Science," as one peculiarly appropriate to the time and the occasion.

Seven years ago, at the Nashville meeting, I was called, by the members of what was then Section A of this association, to take the chair, in the absence of the regularly elected vice-president for that meeting, and performed the pleasant task of reading an address, prepared by him, on the "Endowment of Science." Before the meeting of 1878, at St. Louis, in the regular course of my duties as vice-president, and as chairman of the same section, it became necessary to prepare an address to be delivered before the association, and the subject then chosen was "The Philosophic method of Advancement of Science," or, perhaps more explicitly, The Science of the Advancement of Science. In the first of these addresses, the attention of the association was earnestly called to the necessity of increasing the efficiency of scientific work, and of making most fruitful the labor of the comparatively few workers in this field, in the United States, by securing such an endowment of research as is now, fortunately for our nation, becoming usual in the departments of higher education. In the second of these discourses, I endeavored to point out what, in my opinion, is the truly scientific method of securing the greatest possible results with minimum expenditure of life, strength, mind and matter, and at least cost to the world.

I defined science, substantially, as knowledge systematically organized. I then called attention to the facts that it consists of two divisions: knowledge of phenomena gathered by observation and experiment, and knowledge of laws controlling and correlating these phenomena. As then stated, "all science is thus made up from the infinite number of facts which are comprehended in the universe of the known and the to be-known. Its existence is assured by the stability of all those principles of philosophy which are woven into the connecting chain." "The man of science, the philosopher whose task it is to create and to advance all human knowledge of the great kingdom of nature, is, therefore, a discoverer of facts, an observer of phenomena, a student of Nature's laws. He is a systematic recorder of facts, and a codifier of laws." It was shown that all science has for its foundation the great, the fundamental principle of the indestructibility of "the two products of creation, matter and force, and the fruit

of their union, energy." The next step in the argument led to the classification of the forces of nature into physical—including chemical—vital, mental, and "the master-power, Omnipotence, which is the source and the sustainer of all existences," and this division leads naturally to a similar division of science into physical, biological and mental sciences. It is with the first of these grand divisions of science, only, that we are concerned.

The scientific method of advancing science was shown to comprehend a systematic collection of all facts and phenomena, as exhibited to the senses in the course of our experience, either by simple observation or by carefully conducted experiment; the systematic arrangement of the knowledge so obtained, and the registration of this knowledge in natural order and relations: the study of such recorded facts of science with the purpose of ascertaining the laws that define their relations; the similar co-ordination of separate collections of such related facts and laws, for the purpose of detecting the character and the mathematical form of the more general laws that may determine the relations of group to group and of science to science; and, finally, the aggregation, if it prove to be possible, of all science into one universal system comprehending all the phenomena of nature.

To accomplish this great work there are needed several classes of workers, each of whom, to secure maximum efficiency, must be a specialist, and must give his time and his thought and his strength mainly to a single line of work. We must have observers, each of whom should be fitted by every natural endowment for the study of nature, and for the investigation, by direct experiments intelligently planned and skillfully conducted, of the natural phenomena which are characteristic of, and, perhaps, peculiar to, his branch. We must have philosophers capable of perceiving and expressing the relations of the phenomena so collected, and of thus revealing to us the laws of each of the sciences. We need men who can perceive and exhibit the relations of the several sciences to each other, and their positions in the scheme of universal science. Finally, we require a still larger and more directly useful class, the teachers of science and the no less important body of laborers who make application of science in all the arts of daily life and work.

But all of these classes being organized, and all the fields of work open to man being assigned to them, each taking his proper division of the great task, progress would be but slow, and, in these days almost at a standstill, but for the aid of still another body of co-laborers, who, without pretending to deep knowledge in any division of science, without possessing talent for research, either in the laboratory or in the study, and unable often to realize all the beauty and all the importance of the mighty work that they are helping on, nevertheless generously devote the fruit of years of toil and the product of enormous activities and energy to the cause. These are those who have given, and who are still generously and liberally giving, material assistance by their splendid contributions to the scientific departments in our colleges and of our technical schools. The endowment of research, which will certainly ere long become an acknowledged and legitimate division of this work, is, after all, as essential an element of the scientific method of advancing science as either of the others. Those who give of their substance to aid in the promotion of science are entitled to hardly less honor than those who devote life and health and strength to the good work. Those who take part in the endowment of research are the truest and greatest of modern philanthropists.

When we have thus ascertained what is the philosophic method of the advancement of science, and have determined how we may most efficiently carry on the work in the true spirit of the "science of science-advancement," we may find it to our advantage to pause, and to ask to what end is all this labor to be applied. What is the object of directing this enormous array of intellectual power into the field of scientific inquiry? Having settled upon the form of the system, and the details of the mechanism by which this development of science is to be secured with greatest ease, accuracy and rapidity, to what purpose is this great scheme to be applied? What is the use, and what is the object, of systematically gathering knowledge and of constructing

a great, an elaborate, system having the promotion of science as its sole end and aim? What is "The Mission of Science?"

The mission of science is the promotion of the welfare, material and spiritual, physical and intellectual, of the human race. It has for its purpose and its object the improvement, in every imaginable way, directly and indirectly, of the mind and the body, the heart and the soul, of every human being. It is charged with the duty of seeking the cause of every ill to which mankind is subject; of finding a remedy for every misfortune to which the race is now liable; of ameliorating every misery known to sage or savage; of seeking ways of giving to all every comfort and all healthful luxuries; of reducing the hours of toil, and offering to the relieved laborer intellectual occupations that shall at once take from him all temptation to waste his life in indolence and dissipation and give him aid in his feeble efforts to climb upward into a higher life; of enlightening the world intellectually; of giving it leisure to perfect itself ethically, and to gain those elements of character that are so sadly crushed out by the terrible pressure of our incomplete civilization, sentiments of honor and justice, feelings of love and sympathy, and a spirit of devotion that can only be found highly developed in either the simple child of nature, or in the soul that has time, in the midst of a driving world, to reflect, to aspire and to grow. The true mission of science is one that extends far beyond the workshop of its servants; it extends far beyond our ken, and beyond the range of our mental grasp and farthest view. The great fact that material prosperity is the fruit of science, and that other great truth, that as mankind is given opportunity for meditation and for culture, the higher attributes of human character are given development, are the best indications of the nature of the real mission of science, and of the correctness of the conclusion that the use and the aim of scientific inquiry are to be sought in the region beyond and above the material world to which those studies are confined.

The Mission of Science will be fulfilled in precisely the degree to which it assists us in the protection and preservation of the individual, of the family and of the nation; just so far as it aids each member of the race to attain the alloted term of life, continuous health, and a maximum of happiness, while, at the same time, giving him the opportunity to assist his neighbor most effectively in the endeavor to reach the same ends, and so far as it stimulates him to do well every duty that comes to him whether in his private or his public relations. It will aid every citizen in his efforts to gain the most that can be secured by the practice of industry, skill, intelligence and frugality, to obtain the comfortable independence that every man hopes to enjoy in his old age, and the means of carrying his children on to a higher plane than that upon which he himself entered when taking up his life's work.

The methods properly adopted in the endeavor to prosecute this mission, so far as they relate to the development of the sciences, have been already summarized. It has been seen that the method is in itself scientific. Science first observes, then experiments with a view to the revelation of new facts and unknown laws by systematic research, then applies the power of logic to the construction of an organized, complete and exact system of definite knowledge. First she collects facts and records phenomena, then she seeks to discover and exactly to enunciate the laws controlling them, and finally produces, by the intelligent use both of induction and deduction, a symmetrical and perfect whole. Thus she creates systems of knowledge, and thus she will sometime, we may hope, knit these several systems into one great all-embracing system of the universe.

But, while this scientific method of advancement of science is evidently that which will yield the greatest returns, it is not the fact that we are indebted to such philosophic methods for the production of the modern sciences. It is a fact which is more significant than surprising that, as Whewell remarks, "art has always gone in advance and science has followed to give the reasons for the phenomena discovered and the methods found best in art." "Art is the parent, not the progeny, of science," and, while it is true that progress is always most rapid and most satisfactory when art and science go hand in hand, it has been al-

most invariably the case that art has struggled painfully and haltingly, and doubtfully onward, in every department, slowly and unsteadily advancing, yet almost always going before science, who should have been her leader, her teacher, and her most powerful supporter. This fact is not to be considered as representing a natural state of things nor as in the slightest degree discouraging. Like every art, science, in each of its departments, has been passing through a period of infancy, during which it knew neither its powers, its object or mission, nor its proper methods of work. It required protection and the aid of art until it should be fully formed and competent to take up its labors and to requite the assistance which had been given it. In the past the arts have led; in the future we shall see science leading and directing every development of the arts. History tells us that bleaching and dyeing were familiar arts before the science of chemistry had a name; the inventor of gunpowder lived before Lavoisier; the mariner's compass pointed the seaman to the pole before magnetism took form as a science; the steam-engine was invented and set at work, substantially in all essential details as we know it to-day, before a science of thermo-dynamics was dreamed of; the telegraph and the telephone, the electric light and the railroad, have made us familiar with marvels greater than those of fiction, and yet have been principally developed, in every instance, by men who had acquired less of scientific knowledge than we demand to-day of every college-bred lad.

But all this is of the past. Science has attained a development, a stature and a power, that gives her the ability to assume her place in the great scheme of civilization. Hereafter she will direct and will lead. The blind, scheming ways of the older inventor will give place to the exact determination, by scientific methods, of the most direct and most efficient way of reaching a defined end, methods now daily practised by the engineer in designing his machinery. Instead of long, discouraging, and painful, efforts to reach a result which is indistinctly defined, science will, hereafter, first determine just what is the end to be sought, and then will show the direct line to that end. Uncertainty will give place to certainty, and wasted work will be reduced to the least possible amount.

The aids to science have been already briefly referred to. They are partly material, partly moral, partly intellectual. In the very infancy of civilization the most efficient aids were tendered freely to science. The rulers of the earliest historic nations gave encouragement to the sciences, such as they were in their day; governments founded universities in the days of the Greeks and the Romans; the greatest minds of those times were led to turn their attention to philosophy, and students in thousands thronged the schools. Aristotle made a rude yet definite beginning in the physical sciences; Alexander endowed research most liberally in the person of his great master; the same great warrior urged upon Nearchus the prosecution of the greatest of his plans of geographical exploration, and gave him means to carry out his schemes; an enormous library at Alexandria furnished the student the then available knowledge of the world; the enormous "museum" in which it was preserved gave an impetus to science that has never been lost; Euclid, Archimedes, Eratosthenes, Hipparchus and Hero, those wonderful men who gave us geometry, taught us the elements of mechanics, the principles of hydrostatics and the lever, founded systematic astronomy and physical geography, put on record the earliest notions of the correct form of the earth and the motions of the moon, catalogued the stars, and measured their angular distances, and who first used and described the germ of the steam engine and a thousand other mechanical inventions, were themselves the product of an enlightened policy.

The Arabians transferred the seat of science to the west, and erected her capital at the shore of the Atlantic. Experimental science there had a new birth, and the wealth of the Saracens, and the intellect of the greatest among the Moors and the Jews, there contributed to the growth of real knowledge. Alchemy, the parent of chemistry, was there born, and her progress has never since been interrupted. Marcus Graecus' gunpowder, the more powerful acids, phosphorus, and systematic chemical methods of investigation, are some of the products of the intellectual activity of that time.

Centuries later, and after a period of stagnation and darkness, the light again flashes up and this time it appears in what is now the home of European civilization. The extension of commerce leads to maritime discovery; the awakening of the people by these, to them, startling discoveries, leads to progress in every direction. Galileo and Bruno die that science may forever live; the invention of the telescope stimulates astronomical discovery, and the formation of the modern science of the solar and sidereal systems; the magnificent labors of Newton illustrate the progress of the sciences of physics and mechanics. Every branch of natural philosophy grows and puts forth branches in turn, and the idea of the universal dominion of physical laws becomes accepted as a foundation principle in science, and as the basis of the operations of the universe. Geology, ethnology, physiology, the broader science of biology, take form and grow with astonishing rapidity; and, with their growth, come the minor sciences and the enormous mass of underlying facts determined by the now well-established methods of scientific investigation. Finally, in the later times, in which the last three or four generations have borne a part, science and art have learned to work together, and have gone on, hand in hand, each aiding the other, art supplying facts, science finding out nature's laws as illustrated in those facts, and both, gradually, and more and more rapidly and fully, revealing the beautiful and wonderful system upon which the world is constructed, and all its curious operations carried on, while, at the same time, applying useful knowledge, thus acquired, in promoting the welfare of the human race. Electricity and magnetism, light and heat, and every form of physical energy and of active force, have become revealed to man in all their relations, and in all their methods of operation. Discoveries in physics and chemistry succeed each other with a rapidity that taxes even the specialist who endeavors to keep himself informed in regard to them. Mechanical inventions crowd into our life with such wonder-working results that every day sees a new task accomplished that, the day before, would have been regarded as little less than miraculous. The human voice is transmitted a thousand miles, the written word is sent across the bed of an ocean three thousand miles wide, almost in less time than is required to write it; the traveler breakfasts at Boston, dines at New York, and sups at Washington on the same day. Ten thousand tons are transported from continent to continent, over fifty degrees of longitude, in six days; one workman, with the assistance of machinery, produces more than, a century ago, could a hundred men, doing their best, in the earlier rude ways. We read, in the beam of light, the distance and the rate of motion of the stars, and learn in the same wonderful system of ethereal waves, to determine the nature of the matter of which those stars are composed. Man is turning his work in the world over to the more exact and more powerful machines that he has devised and built, and machinery here weaves his cloths, there gathers his grain, and yonder makes for mankind other machines, doing its work with a strength that is never over-taxed, and an endurance that is never found to reach a limit. Relieved from bodily toil, mankind is coming to that condition of social life in which mental activity absorbs its surplus energies, and the material and intellectual development of civilization are carried on together, and with continually accelerated progress.

This is the history of the past, and this is the picture of the growth of science which we are to study to obtain an idea of what shall be its future. Whenever and wherever the mind has been set free to study and to meditate, to observe and to experiment, science has advanced, and the whole race has felt the benefits of her labors.

This work of science has always demanded the material assistance of acquired wealth, and has given to the investment so made its highest return, its best and most bountiful reward. Whenever and wherever, in the future, science shall have the substantial aid that she needs to secure permanent and convenient quarters, and to prosecute her work, then and there will the progress of mankind be accelerated; and this acceleration will be in proportion to the completeness with which the scientific method of promotion of science is adopted. The characteristics of stationary periods, ac-

cording to Whewell, are "obscurity of thought, servility, an intolerant disposition, and an enthusiastic temper." Science teaches exactness and clearness of thought and expression, perfect independence of mind, the most absolute tolerance of honestly held and frankly expressed opinion, and a quiet coolness of action and a deliberation, however enthusiastic may be the nature of the individual, that may be depended upon to yield a correct judgment. The rapidity of recent changes in our methods of work is due very largely to the introduction and extension of these characteristics of the scientific method, and to the influence of the scientific spirit upon mankind.

It is only in modern times, and since the old spirit of contempt for art, and of reverence for the non-utilitarian element in science, has become nearly extinguished, and since our systems of education have begun to include the study of physical science, that we have had what is properly called a division of "Applied Science." In the days of classical learning, science was only valued as it developed a system of purely intellectual gymnastics; the old Socratic spirit still survives, but is fortunately without influence upon our modern life. Socrates rejected and condemned all physical and mathematical science, and, seeking to impart his own contempt for real knowledge to his disciples, urged upon them the study, exclusively, of ethical philosophy, while, at the same time, himself failing to give to his followers a real system of morals. He accused men of science of reaching vain conclusions, while he was himself lost in the labyrinth of his own indefinite and baseless speculations. Plato followed in the same track, developing splendid ideas by uniting the power of a great intellect with the brightness of primitive imagination, and awakening noble sentiments while giving no assistance to his poor fellow-creatures who desired to conquer the necessary leisure for the enjoyment of life. Aristotle in physics, and Zeno in ethics, employed the scientific method, but their achievements were only appreciated in proportion to their inutility. Archimedes was the most perfect prototype, in those days, of the modern physicist and mechanician, of the scientific man and engineer; yet he, and all of his contemporaries, esteemed his discovery of the relation between the volumes of the cylinder and the sphere more highly than that of the method of determining the specific gravity of a solid or the composition of an alloy, and deemed the quadrature of the parabola a greater achievement than the theory of the lever which might "move the world." His enumeration of the sands of the seashore was looked upon as a nobler accomplishment than the invention of the catapult, or of the pump, which, twenty-one centuries after his death, still bears his name.

No system of applied science could exist among people who had no conception of the true mission of science, and it was not until many centuries had passed that mankind reached such a position in their slow progress toward a real civilization, that it became possible to effect that union of science and the arts which is the distinguishing characteristic of the age in which we live. It was not until the middle of the sixteenth century that Copernicus and the modern system of astronomy became possible; Columbus lived but a little earlier; Gilbert, also, a little later, supplied a basis for the science of magnetism; Galileo applied his genius to the production of the telescope. His first use of the new invention was to earn martyrdom by its application to the proof of the truth of the Copernican system, one of the most splendid of all the achievements of applied science. The revelation of the phases of Venus was one of the facts which marks the conversion of the world from the old Greek methods of scientific thought. It was not until the middle of the fifteenth century that Europe could produce a Leonardo da Vinci, the first of the great mechanics and engineers of modern times. Taking up the work of applying science where his predecessor, Archimedes, had left it, seventeen centuries before, he accomplished an amount of work in the application of the physical sciences and of the science of mechanics, that few men in later times have been able to approach, and none, probably, to equal. He revealed the theory of the lever, extending the work of Archimedes to the more general case; he was acquainted with the laws of hydraulics, understood the nature and effects of

friction, and, to a certain extent, its laws. Stevinus followed da Vinci, and Galileo's treatise on mechanics, which appeared in 1592, and his "dialogues" of 1633, crystallized the knowledge of his time in accessible and practically available form. Then came Torricelli, and, a little later, that greatest of English philosophers and mechanicians, Newton, whose "Principia" has been, from 1686 to the present time, a mine which has richly repaid all the less illustrious workers who have chosen to explore it. This wonderful geometer gave all his mighty intellectual power to the work of usefully applying science. He enunciated the laws of motion, deduced the law of gravitation, proved, by the application of his cumbersome but fruitful methods, the exactness of Kepler's laws, showed their generality, and pointed out the fact that they hold the planets in their orbits, and sway the whole stellar world.

The time of Newton marks the beginning of a grand outburst of energy in the useful application of the sciences. Every art, every industry, every phase of human life, felt its helping hand. Inventions began to appear, to relieve the delving laborer, in every department of human industry. The arts began to find a scientific basis, and to look to science for aid in their perfection and in their development; the industries began to feel the stimulating effect of scientific discoveries, and of the introduction of scientific methods of application of practical knowledge; Descartes, Newton and Leibnitz advanced mathematics to a point from which only a Hamilton or a Sylvester could carry it further; Lavoisier and his contemporaries, only a century before our own time, created chemistry; geology had its birth almost within the memory of our elder colleagues; the several departments of physics have taken definite shape almost within our own shorter memories; the natural sciences have come into being since the time of Cuvier and Linnaeus; the greater science of "energetics" is hardly yet defined, and has not taken its place in the text-books taught in even our schools of science. We are, in fact, at the very threshold of the true era of applied science.

In illustration of the gradual evolution and growth of correct theory, and of this slow development of rational views, of the methods of scientific deduction, and of the invariably tardy progress from a beginning distinguished by defective knowledge and inaccurate logic, in the presence of what are later seen to be plainly visible facts, and of what ultimately seem obvious principles, observe the rise and progress of our hardly yet completed theory of that greatest of human inventions—the steam-engine.

Studying the history of the development of this theory, it cannot fail to become strikingly evident that, throughout, experimental knowledge and practical construction have been constantly in advance of the theory, and that the science of the conversion of heat-energy into mechanical power has, in all stages of this progress, come in simply to confirm general conclusions previously reached by deduction from experience and observation, to give the reasons for well-ascertained facts and phenomena, and often—not always promptly or exactly—to define the line of improvement, and the limitations of such advance.

The theory itself began by the correlation of the facts determined by the experiments of Rumford and Davy, at the beginning of the century, those announced by Joule and Thompson many years later, and the laws developed by Clausius, Rankine, and Thompson, at the middle of the century. But Watt had discovered the facts which have since been found to set limits to the efficiency of the engine, a hundred years ago; Smeaton, in many respects, the greatest mechanical engineer of his time, made practically useful application of the knowledge so acquired, and endeavored to secure immunity from these wastes by thoroughly philosophical methods. Clark, a generation ago, showed how the losses first detected by Watt set a definite limit, under the conditions of familiar practice, to the gain to be secured by the expansion of steam; and Cotterill within a few years has shown, by beautiful methods of treatment, their magnitude, and how these wastes take place. Hirn and Leloutre, in France, have similarly thrown light upon the phenomena of "cylinder-condensation," and De Fréminville has suggested the method of remedy. Yet it is only now that we are beginning to see that the philosophy of

heat-engines is not simply a thermo-dynamic theory, and that it involves problems in physics, and a study of the methods of conduction and transfer of heat without doing work from point to point in the engine. We are only now learning how to apply to knowledge gained by Isherwood twenty years ago, and by Hirn and by Clark still earlier, in solving the problem of maximum efficiency of the steam-engine. We have only now discovered that the "curve of efficiency," as I have taken the liberty of calling it, is not the curve of mean pressure for "adiabatic" expansion, as Rankine called it, for "isentropic" expansion, as Clausius would call it, but that it is a curve of very different form and location, and that it is variable with every physical condition affecting the working of the expanding fluid in the engine. We have only now learned that every heat-engine has a certain "ratio of expansion for maximum efficiency," which marks the limit to gain in economy by expansion, which limit is fixed for each engine by the nature of the expansion, and the method and extent of wastes of heat. All the facts of this case were apparently as obvious, as easily detected and weighed in their influence upon the theory of heat-engines, years ago, as to-day. Even the latest phase of the current discussion of efficiencies of heat-engines, that relating to their commercial efficiency, would seem to have been as ready for development a generation ago, when first noted by Rankine, as to-day; yet, what is now known as a simple and easily formulated theory has been several decades in growing into shape, notwithstanding that all the needed facts were known, or readily determinable, at the very beginning of the period marked by its evolution. It is only within a year or two that it has become possible to say that the theory of the steam-engine, as a case in applied mechanics, has become so complete that the engineer can safely rest upon it in the preparation of his designs, and in his calculations of power, economy, and commercial efficiency.

Even in the lowest department of applied mechanics, that which forms the basis of the work of the engineer—that including the study of the materials of construction—our knowledge, scientific or general, has been wonderfully slow of development. Experimental work may be said to have commenced in this field a century ago, and the labors of Muschenbroeck, of Tredgold, of Barlow and of Hodgkinson, of Fairbairn, and of their coadjutors of the first half of the century, gave to the constructor and to the theorist the facts which were most essential to their work. But it is only within the past few years that the conditions modifying the value of these materials, as applied in engineering, have been carefully and critically studied by the light of experimental investigation. The effect of heat upon strength and elasticity, the alteration of structure produced by vibration, the difference in carrying power and in safe loading, due to reversed stresses, the modification of the value of steel by alteration of chemical composition and by various modes of tempering, the effect of that singular phenomenon, the variation of the normal line of elastic limits by strain, the persistence of the effect of strain in the production of cold-worked iron and steel, and in the permanent record of the results of accidents straining structures—all these have been matters left for the present generation to investigate.

It is only to-day that we are beginning to ascertain the existence of alloys and special modifications of iron and steel which adapt these metals to special purposes, and the engineer is only now becoming accustomed to the writing of specifications including details of the composition and character of the materials to be used in his work. The use of manganese steels and bronzes, of the phosphor bronzes, and of various other deoxidized alloys, the search for the exact location of the alloy of maximum possible value for specified purposes; the continuation of researches in regard to the effect of prolonged loading of materials and of structures; these and similar matters are those which are receiving the attention of the engineer of our day, and are merely the beginnings of a *renaissance* in applied mechanics which is likely to reveal wonders where they have been least expected and most rarely looked for.

But the slow progress of scientific development in matters relating to common practice in the useful arts is hardly less remarkable than the difficulty with which

scientific principles, even when well established and well known among scientific and educated men, sink down into the minds of the masses. Perhaps no principle in the whole range of physical science is better established and more generally recognized than that which asserts the maximum efficiency of fluid in heat engines to be a function, simply, of the temperatures of reception and rejection of heat, and to be absolutely independent of the nature of the working fluid. This was shown by Carnot, sixty years ago, and has been considered one of the fundamental principles of thermo-dynamics from that time to this. Nevertheless, so rarely is it comprehended by mechanics, and so difficult is it for the average mind to accept this truth, that the most magnificent fallacies of the time are based upon assumptions in direct contradiction of it. The various new "motors" recently brought before the public with the claim of more than possible perfection, have taken hundreds of thousands of dollars, within the past two or three years, from the pockets of credulous and greedy victims. It is not sufficient to declare the principle; the comparison of steam with ether, and of air or gas with carbon-disulphide or chloroform, must be made directly, and the results presented in exact figures, before the unfortunate investor —whose rapaciousness is too often such as to cause him to give ear to the swindler, rather than to the well-informed and disinterested professional to whom he would ordinarily at once go for advice— can be induced to withdraw from the dangerous but seductive scheme. It is true that the principle does not as exactly apply to a comparison of efficiencies of machine, and that the vendor of new motors usually seizes upon this point as his vantage ground; but a careful comparison of the several fluids, both as to efficiency of fluid and efficiency of machine, throughout the whole range of temperatures and pressures found practicable in application, such as has recently been made under my direction, shows that the final deduction is substantially the same for all the usually attainable conditions of practice, and, further, that of all the available fluids, steam is, fortunately, the best.

It is only since our political body became a nation that the application of scientific methods of experiment led that great engineer, James Watt, to the invention of the greatest of mechanical civilizing agents, the modern steam-engine. It is within the life-span of many who are still living that the art of spinning, the art of weaving by machinery, the production of the cotton gin, the invention of the sewing machine, and a thousand other now familiar and essential factors of our present life, have been born of this union of science and art. The locomotive, the steamship, the telegraph, the telephone, are all younger members of the same family—the mighty progeny of that mightier pair. The world has learned to value science for her beneficence, for her fruitfulness, for her helpfulness. It has learned that to a true union of science with art only, are we to look for the methods and the means by which mankind is to be finally, if at all, emancipated from the yoke of overburdening labor now so terribly oppressing the race.

The cultivation of science, in its relations to every branch of the arts, and to every department of the industries of the world; the collection of practically important facts, and the discovery of its essential laws, as forming a system of application of science, is, as is now sufficiently evident, the task which lies before every scientific worker. It is further evident that there must be inaugurated a *system* of cultivation of science that shall promote the advancement of scientific knowledge, and that shall aid in the application of science to the daily work of humanity. We have seen what such a system must be, and how it must be developed and set in operation. In the carrying out of this system of promotion and cultivation of science, we are to see that men of science are given all necessary assistance in their noble task; and the way in which this aid is to be obtained and made effective has been already discussed at sufficient length. But, when this part of our work has been satisfactorily organized and set in operation, we have the no less important task left us to see that the knowledge so acquired shall be preserved and communicated to the new generation. This leads us to consider our methods of education.

Glancing back into history, we find that the distinction which I have pointed out between the old and the new schools

of philosophy and of thought has been equally marked in the methods of education of the older civilization and the new. Only a few decades have passed since the only education that could be obtained in our schools was one embracing merely the purely literary and the speculative, with a small allowance of pure mathematics. The languages, history, literature, the elementary mathematics, and the old systems of speculative philosophy, were the principal subjects taught in our colleges. Gradually, the natural and physical sciences came in, and were given a subordinate place in the college course, and then only under protest. The stereotyped argument for the retention of the old system, to the exclusion of the new, was, and is to-day, the assertion that the old system strengthened the intellect and broadened the views of the student, while the new subjects were *merely useful.* The fact that the study of science is the most effective of disciplines for the reasoning faculties, for the memory, for the judgment, and for the very faculties for which the older instruction is claimed to do so much, is not even now perceived, far less admitted, by many of our most distinguished and ablest educators. But, in spite of all difficulties arising from ignorance, prejudice, habit and opposing interests, the study of applied sciences is becoming as well established, as part of the modern college course, as is that of any branch of pure science; and the study of pure science is very steadily becoming a more important part of the standard system of general education—of "liberal" education—while, at the same time, it is gradually becoming changed in its form of presentation, to adapt it more perfectly to its subsequent use in application. Speculation is everywhere losing its place, and investigation and systematic research are advancing to occupy the deserted ground.

The modern method of education is becoming thoroughly systematic. It involves the introduction of scientific methods of promotion of the efficiency of instruction; it includes the careful study of every detail of the educational system, and of the whole course of tuition, determining what methods are the most fruitful of useful and practically valuable results, what are the subjects, and what the methods of presentation, which give to the learner the largest amount of permanently retainable and widely applicable knowledge. Our primary education has always, and necessarily, been distinguished by the predominance of the scientific method and of the practical side. We have not been driven so imperatively toward this use of scientific methods, and of application of the sciences bearing upon common life, in the higher education; but the wisdom and the expediency of a modification of old ways, in this respect, is now rapidly becoming acknowledged, and the new education may be considered as fairly and safely introduced. We may call it the modern systematic method, the scientific method, of education. Science will never, we may be sure, displace entirely the older departments of education; but science will henceforth take a place beside them as no less valuable for mental discipline, and as the essential factor in the promotion of progress in all the arts and employments, in all the daily life and work of the world.

And not only may we feel assured that science will never entirely displace the older systems of education, although certain soon to take her rightful place beside literature and philosophy, and her own most efficient servant, mathematics; but we may plainly see that the time is not far distant when we shall have, for those who propose making science their mistress, and for those who are to make the work of their lives the application of science to the arts and the humbler industries of the world, "schools of science in every city, colleges of science in every State," and universities of science, pure and applied, as the base of the great pyramidal educational system. And it may be anticipated that when the system shall have become perfected and of full growth, it will be the universal custom of those proposing to study in these advanced schools, to secure, first, the general education, the broad culture, and the disciplinary preparatory training, that the academic schools now give, before entering upon the special branches of study that are to be continued through their later lives.

Students of science will enter these professional schools from the colleges of the country, precisely as they now enter the medical schools and the schools of law, making their professional studies

post-graduate courses. The line will thus lie through the primary schools, which are becoming each year better fitted to give the child the best introduction into a life either of labor or of study, through the higher schools, in which instruction is daily becoming more practically valuable, both in the imparting of knowledge and in mental discipline, through the college, where the discipline already given will make the student capable of securing good and permanently valuable knowledge, into the scientific school, and, in many cases, onward and upward into the university of sciences, in which all science is specialized for those who propose, as every scientific man must, to devote themselves wholly to scientific work.

Thus, ultimately, will science lead, direct, and most efficiently aid, the nation in its progress toward the ideal, yet approachable, social state which has been the hoped for, if not the promised, land of every great political and social economist and philosopher, from the days when Cicero thought it his greatest honor to have written "On the Commonwealth," up to the present time. According to Cicero, the Roman Commonwealth, "by defending its allies," took possession of the world. Our own grander commonwealth, by defending and sustaining her as yet hardly recognized, but most powerful and most beneficent ally, Science, will, some time, control, and for vastly grander purposes, a greater world.

The place of these modern methods in our political and social system can now be readily determined. Had it been asserted a generation ago that science should control our politics and dictate in every movement of our social system, and that it should be the guiding star of every political economist and of every philosopher, whatever his province, the claim would have excited a smile, and would neither have received consideration nor provoked rejoinder. But we shall see that this is precisely the place which will be ultimately, and of necessity, taken by science, and that it is to science that every great movement, whether political or social, industrial or ethical, must look for intelligent direction.

The object of every correct system of government is to secure to every member of the society which it guards protection of life and property, liberty to earn as much wealth and to secure as many of the comforts and luxuries of this life as he may, and opportunity to prepare the coming generation most effectively for successfully doing the work that lies before it. This is not the object accomplished by the old governments. They were established for the purpose of promoting the welfare of ruling individuals, or of ruling classes, and the result of their control of society was, invariably, the elevation of the one class at the expense of the other; the rulers flourished at the cost of those who were ruled. Modern systems of government are continually approaching that ideal form in which the people govern the people, and in which the public good and the security of the citizen is the end sought. But, as it is the end and aim of every good government to promote the welfare of the citizen by purely general legislation, and by the enforcement of laws enacted without reference to individuals or classes, it becomes the duty of the citizen who appoints the legislator, and of the legislator who makes the laws, to seek the scientific, the logically and the ethically correct, method of promoting general welfare. It is here that science, at the very start, becomes properly our guide. The government is charged with the duty of guarding and promoting every legitimate industry, of giving every citizen the means of preparing himself to do his work in the world and of developing, in every proper way, the natural resources and the appropriate industries of the territory over which it has control. How this can best be done it is the province of science to point out. Men of science, each in his own department, are the natural advisers of the legislator. Citizens and legislators are both entitled to claim this aid from those who have made the sciences of the several arts their special study, and from those who have devoted their lives to the study of the sciences of government, of social economy, and of ethics.

Of all the many fields in which the men of science of our day are working, that which most nearly concerns us, and that which is of most essential importance to the people of our time, is that department of applied science which is most closely related to the industries of the world. The two great needs of mankind to-day are, first, an education that shall enable the

workers to acquire all the necessaries of civilized life, a fair share of the comforts, and even some of its luxuries; second, such provision for the non-workers, deserving but invalid, willing but impotent, as shall insure them against actual suffering, and, if possible, give them some compensation, in the short remainder of life, for their misfortunes. By thus reducing the suffering existing in the world, science will accomplish its highest mission. Government has two main objects to secure: the suppression of crime and the promotion of industries. It is in the latter that applied science finds its plainest and its most obvious line of application, and in such application, as we shall readily perceive, the department of science which must find widest and most important fields of application will inevitably be that of "Mechanics."

Mechanics directs the advancement of the world in an astonishingly greater degree than does any other department of science, and it has, therefore, correspondingly great importance as one of the great agents of civilization. Every industry is largely mechanical; nearly all of the products of the labor of the world are given form, to a greater or less extent, and usually principally, by mechanism. It is applied mechanics that sows and reaps our grain, that grinds our flour, that transports it to domestic markets, that carries it across the ocean to the half-fed people of Europe; it is applied mechanics that prepares our cotton for the mill, that compresses the product of acres into a bale that may be handled by a single strong man, that spins our cotton and our wool, weaves them into cloth, and even cuts the cloth to pattern, and, by its most ingenious of minor applications, the sewing machine, gives the garment permanent form. Applied mechanics gives to the astronomer his telescope, enables him to calculate the elements of the planets and the stars, teaches the mariner his system of navigation, gives him the ship that he thus directs, guides the engineer in his magnificent work of designing the machinery which impels the enormous structure. Even the sister sciences, physics and chemistry, are departments of applied mechanics, and are coming to take their place in the wide spreading department of "molecular mechanics," and in a still more comprehensive but younger branch of our science—that of "energetics."

Even vital forces are gradually coming to be grouped under the same head, and all the natural sciences are more and more generally recognized as properly falling into the department of energetics, and as illustrations of the application of the laws of mechanics. The Mission of Science is to be fulfilled mainly, then, through the application of mechanics.

How the application of our beautiful and noble science is to promote the welfare of the race by the solution of the apparently abstract problems which everywhere challenge the student of science may not always be readily perceived. The mechanics of the ether, the determination of the exact measures of its elasticity and density—of which we only know to-day that the one is probably as enormous as the other is inconceivably small—the character of its vibrations, the method of distribution of its molecules, their magnitudes and distances, and the extent of their movements; the methods of conversion of mechanical energy, or of other forms of energy, into light and into heat; the great problem of transformation of heat into mechanical energy without waste; the still greater problem of the direct transmutation of the work of chemical combination into other forms of work and power; the discovery of the nature and method of operation of those forces which give rise to chemical and electrical energy; the method of conversion of the two forms of energy, the one into the other, with maximum efficiency; all these are problems that confront the investigator to-day, and all have, directly or indirectly, although it may not be easily seen just how, a real bearing upon the prosperity of the race. Those more directly "practical" problems, such as the discovery of a means of making non-conducting working cylinders for our heat-engines; the production of the electric arc without variation of intensity of light; the development of mechanical power with absolute steadiness and uniformity of speed; the concentration of power for aeronautic applications; the application of the mechanic's inventive power to the cheapening of all the methods of production and supply of the perishable necessaries of life; all these are obviously within the province of our

science in the prosecution of its beneficent mission. But it is not enough that it shall be made possible that one pair of hands shall do the work of two ; work must be found in new fields for the pair of hands thus thrown out, and this makes it the duty of science and of its workers to see that new departments of skilled employment shall be opened to surplus labor. Thus the development of new industries becomes as much a part of the work of science in the future as is the improvement of those now existing. The new industries must evidently be mainly skilled industries, and must afford employment to the more intelligent and more finely endowed of those to whom our modern systems of education are offering their best gifts. When this process of industrial revolution shall have been effected, the great mass of mankind will be able to secure by the labor of each day, restricted to such number of working hours as shall best develop and maintain in healthy condition the whole muscular system, all the necessaries and comforts of civilized life, and will yet find time for recreation and for the cultivation of the moral and intellectual faculties, and for the development of all the mental powers and of all the affections.

The progress of science, as seen in her past history, resembles that of the great steamships which are now the embodiment of the most wonderful of the results of human intellect, working through the scientific application of mechanics, which to-day mark the advanced position of civilization. In the building of the steamer long weeks are spent in the preparation of plans, in the calculation of proportions, and in the determination of the form in which the enormous masses of iron are to be grouped; months are spent in gathering the materials together which are to be given shape in the great vessel, and which are to be turned and planed and cast and forged into the pieces composing the mighty engines and lesser machinery; during months and months the tremendous structure lies motionless upon the ways, slowly taking shape, slowly receiving the massive machinery which is to form the vital apparatus essential to the life-like action of that powerful, and hardly less than living, creature; no sign of life or power is seen during this long period of development, and, to the uninstructed observer, it may appear utterly improbable that the dormant mass can ever be more than an inert and useless hulk; yet, after a time, when the period of preparation is completed, and when all that is needed for the purposes intended by the designer and the constructor has been brought together and put in place, suitably connected, part to part, there comes a time when a change and a movement are perceived. A few insignificant pieces of timber are knocked away, and the enormous vessel, slowly and by imperceptible acceleration, moves down toward the water, and, with continually increasing speed, finally rushes into the element which is to be, for all its future life, its home. A halt and a little more delay, and the now fully equipped and self-impelling steamship once more moves. Starting again, with slow and hardly visible motion, by the exertion of her own unseen, but inconceivable power, the great ship gradually acquires velocity, and we see her, later, traversing the ocean, back and forth, over a thousand leagues of water, like an enormous shuttle, weaving bands that tie closer and closer hitherto separated members of a common race, of one human stock, and binding the nations daily into more perfect brotherhood.

So it was with science in the past, and so is it in the present. Long ages ago, in the earliest historic period, was her time of slow and unobserved generation and embryonic growth. All through the middle ages signs were not wanting of her existence and gradual development, in the changing methods of thought of mankind, and in the accumulation of materials to be usefully applied at a later date. At the beginning of the seventeenth century, the first great movement began, and then only did the true purpose of all that earlier period of preparation become evident. A century ago, with the birth of the steam-engine, later, with the introduction of product of the printing press into the daily life of the world, with the apparition of the electric telegraph and the introduction of the railroad, began the real progress of science, and we are now seeing but the beginning of her awe-inspiring career. She has taught us to drive ten thousand tons across the seas, regardless of wind and waves, by the might of our 12,000 horse-power engines

—engines in which steam does more work than fifty thousand actual horses could do, continuously. She has taught us to send printed messages across the oceans and across the continents, girdling the world with her mysterious wire; she has shown us how to drive the railway train, with its hundreds of tons of merchandise and living freight, faster than bird can fly; she has helped us give to the people news of every land, gathered in every clime, and brought to us by messengers swifter than the shadows of the sun, and printed on millions of sheets between the first glowing of the dawn and the rising of the orb of which Aurora is the messenger; she has given practical expression to a myriad of other hardly less magnificent philanthrophies. Yet the mission of science has made but the veriest beginning. It still remains to her to perfect and to systematize a thousand new industries, to invent as yet unimagined new arts, to bring the laborer worthy of his hire all that he needs, and all that he can desire for his own comfort and for the care and comfort of his family, to so adjust the power of production to that of consumption, and both to the working capacity of the world, that the now seeming natural conflict between the employer and the employee, between labor and capital—that fallacy which is the support of every demagogue—shall no longer have even the appearance of existence. She has still to do her part toward the reduction of all systems of government to the one only correct form; that in which the people are governed by the people, for the best good of the people, and in which legislation is solely directed toward the protection of life, of liberty to do right, toward the protection and support of the industries of the country, the sustaining of a system of education that shall give to every citizen the opportunity to fit himself with maximum efficiency for the duties of a well planned life, and the encouragement, in every right and reasonable way, of all that tends to aid the material and the moral welfare of the community.

She has all this and much more to do; and her highest work will be found to include, I think, important modifications of the methods of evolution and of conformation of the race. The enormous advancement of the intellectual side of life must inevitably, as it seems to me, result in the production of a race of men peculiarly adapted to such environment as science is rapidly producing. Thus accomplishing, under the guidance of our science, such tasks as lie before him to accomplish, the "Coming Man," with his greater frontal development, his increased mental and nerve power, his growing endurance and probably lengthening life, will be the greatest of the products of this scientific development, and the noblest of all these wonderful works. And may it not be possible in the better days of that future into which we may now barely get the faintest glimpse, when the increase of the population of the world shall be limited, not as now by the maximum of misery and suffering bearable by the race, nor yet by art, not by a Malthusian system, but by the rate of expenditure of vital power in the operations of the mind, of the intellect, and of the affections, when those who are brought into the world shall have fair prospect of being permitted to lead happy and prosperous lives, when suffering and misery shall have been reduced to a minimum—that we may see man taking the place assigned him by Ruskin? Says that great master of expression: "All the power of nature depends upon subjection to the human soul. Man is the sun of the world; more than the real sun. The fire of his wonderful heart is the only light and heat worth gauge or measure. Where he is are the tropics; where he is not, the ice-world." May not this development of the human soul be, after all, the true Mission of Science?

As a toil-worn traveler, wearily faring homeward at early dawn, skirts the western shore of some broad lake, picking his way by the uncertain, but always increasing, light penetrating the cloud beflecked sky, at last sees in the east the uprising sun, and watches its steadily growing disk, and the wide-extended sheaves and pencils of splendent golden light, silvering and gilding, and magnificently tinting, every snowy pile of vapor, etherializing all the low-lying mist that hides the bosom of the lake, and sees finally, across the rippling waves stirred by the first gentle breezes of the dawn, the flashing of a broad band of glory, each wave at the distant shore catching up its share of the wonderful illumination, each its handful of the beautiful light, each passing it

onward to the nearer swell, and each catching new beauty from the passing beams of the day-god, until the eyes are dazzled by the spreading sheen, and all the scene is surcharged with light, until the glory covers the weary one, lightening his heart, cheering his soul, quickening his step, and sending him homeward, with all his sadness gone, refreshed, hopeful, and happy.

So Man, plodding onward, sad, overburdened, and despairing, toiling wearily over the shifting sands of life, at last has seen, across the expanse of eternity, along the shores of which he wanders, the first bright beams of the light of Science, heralded, but hidden, through a dawn that had lasted for centuries; and, as the bright luminary that is to guide him through all the future, has arisen, steadily and constantly, among the obscuring, but breaking, clouds of the dark ages, the mists have been dispelled, the clouds themselves have received golden and silver linings, and the all-pervading beams, caught and reflected, but always advancing, have finally reached the hither shore, and Man, enlightened and strengthened, with new insight into a brightening life, himself advances, with new courage and renewed hope, toward that future which it is the heaven-directed Mission of Science to illumine with the radiance of ever-increasing knowledge.

CHINESE IRON FOUNDRIES AND RICE PAN CASTINGS.

From "The Chemical News."

Although the Chinese, as a race, are incapable of the deep thought and extreme mental effort required to elaborate the intricate details of modern scientific machinery, or to plan those bold enterprises and extensive systems of road and hydraulic engineering which are the pride and glory of the British civil engineer, yet, *per contra*, it must be conceded that for finnicking, tedious, patient ingenuity of a certain sort, the Chinaman stands almost without a rival. As a notable example of this same patient, plodding ingenuity, shown by the Chinaman in some of his trades and industries, may be instanced the manufacture of the very thin cast-iron rice pans which may be seen in almost any cook-house in the colony of Hongkong. The principle seats of this industry are at the towns of Sam-tiu-chuk, in the Kwei-shin district of the Wei-chow prefecture, and at the busy, populous, manufacturing town of Fatshan, situated in the Nam-hoi district of the Kwang-chow prefecture. This latter town is distant but some twelve miles, in a south-westerly direction, from the provincial capital of Canton, and has, from the extent and importance of its trade and manufactures, notably its great trade in iron goods, tools, and hardware, been aptly termed the Birmingham of China. The previously mentioned town of Sam-tiu-chuk is inhabited principally by Hakkas, and is one of the principal towns of the sparsely populated and mountainous district of Kwei-shin. The iron used is obtained by smelting the magnetic oxide, which is found in large masses in the mountains surrounding the town. The ore is broken up, and smelted with charcoal in a primitive smelting furnace or cupola some eight feet high; the cupola is cone shaped, having its apex, or smaller diameter, at the bottom; the single tuyere pipe is of earthenware, the opening for emission of the blast being placed downwards. The furnace itself is of earthenware, or rather puddled and dried clay, kept from falling to pieces and strengthened by hoops and longitudinal straps of iron; the whole is lined with clay several inches thick; the internal diameter at the bottom may be about two feet, or perhaps a little more, and at the top about three feet and a-half, inside depth about six feet. The blast is produced by a rude yet most ingeniously contrived bellows, formed of a wooden box some five feet long by three feet in horizontal and a foot and a-half in vertical section. This box is divided longitudinally into two compartments, each eighteen inches square in vertical section, in each of which compartment a piston works; the

valves are so arranged that one piston is effective in the up, the other in the down, or rather return stroke, for the machine is arranged horizontally. It will be seen, however, from this arrangement, as there is no air chamber, that the blast is not perfectly continuous, there being a slight cessation at the end of each stroke before the return stroke can be effective. The fuel used is charcoal, and the furnace, being first heated by starting a fire with fuel alone, is then filled up with alternate layers of charcoal and ore in small fragments. The blast is urged, and after a sufficient time has elapsed, the molten metal is drawn off from a tap hole at the bottom in the usual manner, and cast into ingots, which, when intended for export, are afterwards reheated in an open forge, and beaten into blooms of about six pounds in weight; these may occasionally be seen for sale in the iron-dealers' shops in Hong-Kong, and, when made from genuine native iron, fetch a very high price, indeed, as much as four dollars per picul, or even more, being sometimes paid for the best quality made from the black or magnetic oxide. The Fatshan iron, which, to a great extent, comes from Ying-tak (a town on the West River), is smelted from hematite (the red oxide), but mixed to a considerable extent with gangue, rarely pure, and of varying and uncertain chemical composition. The iron smelted from this latter ore, although far more valuable in the native estimation than foreign imported iron, yet does not realize so high a price in the market as the other.

For making the very thin rice pans, which are cast without handles, pure native iron alone can be used; as being smelted with charcoal, it has the property, when melted, of being more fluid than iron smelted with coal; or it may be that the iron itself, being uncontaminated with sulphur, or phosphorus, possesses the property of greater fluidity on this account. The moulds in which the pans are cast require weeks of tedious and patient labor to bring them to perfection. They are composed of two parts—an upper and a lower—and are made of carefully puddled clay, the upper portion about an inch and a half, and the lower somewhat thicker; the lower or under half is full of round holes, about half an inch in diameter, which pierce about two-thirds the thickness of the mould; these holes are made in order to allow the clay to dry thoroughly; the moulds are turned true on a revolving potter's table of the usual pattern, and when quite dry receive a final coating of fine moulding sand, and are made perfectly smooth. The two portions of the mould are then luted together with clay and placed in a large round oven some six feet or more in diameter. The pans are cast bottom upwards, each mould having a runner but no riser; the upper portion of the mould has three little legs in order to support it when drying previously to the two moulds being luted together. After being placed in the oven, which is some two and a-half feet deep, the moulds are surrounded with charcoal, which is fired, and the ovens closely covered with a curiously constructed earthenware, or rather dried clay cover, kept together, as in the case of the furnaces or cupolas previously mentioned, with bands and straps of iron. The process is so timed, that by the time the moulds are at a bright red heat, or almost white heat, the iron in the cupola is melted, and ready for tapping; the molten metal is then run out into ladles made for the purpose, and quickly poured into the moulds. When these are all filled, the cover of the oven is readjusted, and the whole left to anneal or cool gradually.

The great secret about this process, which enables the Chinese founders to cast their iron pans of such large diameter, yet so thin and light as to be scarcely thicker than a sheet of paper, appears to be the use of highly heated moulds, and pure iron smelted with charcoal. When the ovens and their contents are cooled down, which takes about two days, the luting attaching the upper portion of the mould to the lower is carefully removed, and the moulds being separated, the pan can be extracted; when the operation has been successful, the same mould can, with a little touching up, be used several times. The pans now have each attached to its bottom a runner, or lump of iron, of greater or less size, which, from the extreme thinness of the pans, making them but little less brittle than earthenware, requires the greatest care in its removal; these runners are carefully sawn off, the use of the more expeditious cold chisel being more

likely to cause fracture than the slower but steadier saw; the edges are smoothed down, and the pan is ready for the export market. Handles are attached to these pans by the retail dealers, who bore holes near the rim of the pan, and attach small ribbons of iron for the purpose of handles.

The pans made at Fatshan differ from the preceding in being cast with handles attached near the rim to the inner surface of the pan, which necessitates the breaking of the mould at each casting, it being rare for the same mould to be serviceable a second time. The Fatshan pans are also usually cast much thicker and heavier than those of Sam-tiu-chuk, and occasionally as large a proportion as one-third of foreign cast iron, generally Kentledge or ordinary pig iron, is mixed with the native iron for casting. In other respects the process followed at both places is the same. The Fatshan pans being thicker are the more durable of the two, while the thinner Kwei-shin pans are more popular with poor people, because being thinner a less quantity of fire-wood is required to heat them through. The manufacture of iron rice pans is in Kwangtung province a Chinese Government monopoly, which is farmed out by the Salt Commissioner, and by him licenses are granted to the local iron founders on payment of a heavy fee. Considerable care has to be used in packing the pans for export, in order to prevent breakage, which, however frequently occurs when any considerable number of pans are shipped to Australia or other distant ports. An attempt was made, some years back, to cast rice pans in Hongkong, but the locality chosen, Shau-ki-wan, being an unhealthy one, many of the workmen died, others left the place sickly and fever stricken, and the concern from this cause mainly proved a failure. It may, however, be possible that had a longer time, say a year or more, been allowed to elapse for the newly filled-in ground to settle down, and the freshly cut hill side adjacent to finish giving off its malarious exhalations, the place would not have been so unhealthy, and in that case the result might not have been so disastrous to all concerned, as it unfortunately proved itself to be.

ON THE PRACTICAL RESULTS OBTAINED FROM VARIOUS WATER-RAISING MACHINES IN HOLLAND.

By G. CUPPARI.

From Selected Papers of the Institution of Civil Engineers.

TOWARDS the end of the year 1877 the Author visited Holland, and spent a year and a-half in studying the hydraulic works in that country, particularly those for draining land. Having had opportunities of examining the principal works, both finished and under construction, and of taking notes from various documents referring to them, he collected a large amount of information not otherwise procurable.

In the specifications for water-raising machines in Holland, a clause is inserted to the effect that the consumption of Ruhr coal is not to exceed 6.61 lbs. per H. P. per hour. In practice, however, there are great differences in the duty of the engines.

The Rhineland Company. Pumping Station at Halfweg.—This station was erected for the purpose of discharging into the Y (which was converted into a canal in 1873) the waters of the general collecting basin of the great Rhineland Company. The surface of this basin (called "boezem," a Dutch word which will be used throughout the Paper) covers 8,600 acres, when the water is standing at its normal level. There discharge into this basin, naturally, the high lands, 30,443 acres in extent; artificially, the polder lands. These are classified according to the normal water-levels as follows:—

				Acres.
Normal level at 3.28 feet−AP and over.				16,282
"	bet. 3.28 ft. and 5.0 ft.−AP.			60,855
"	" 5.0	" 6.5	"	22,314
"	" 6.5	" 11.5	"	0
"	" 11.5	" 13.1	"	3,249
"	" 13.1	" 14.75	"	3,874
"	" 14.75	" 16.4	"	66,029
"	" 16.4	" 18.0	"	6,731
"	" 18.0	" 19.7	"	7,882

These areas vary year by year in Holland, owing to the increased drying up of the land, the variations in the normal level, &c. The above are the figures for 1867, since which date there have been no changes of importance. The total area of Rhineland is 258,382 acres, but it also receives into its boezem the waters of the Woerden Association, of which the boezem area is 403 acres, and the total area draining into the boezem of Rhineland is 302,590 acres.

When the lake of Haarlem, which was in communication with the boezem of Rhineland, was drained the great diminution in the receiving basin was compensated by providing a better outlet into the North Sea at Katwijk, and three pumping-stations, at Halfweg and Spaarndam on the Y, and at Gouda on the Yssel. In 1880 another was added at Katwijk. The waters discharging into this receiving basin, composed of a network of canals and small lakes, come for the most part from the polders, that is to say, the discharge is performed mechanically. But this first lift is generally insufficient, and a second is required, which is effected by steam pumping-engines.*

The internal conditions of the boezems are,

Mean	water-level (1873–7)	...1.656	feet−AP.
Minimum	" "	...2.297	"
Maximum	" "	...0.656	"
The maximum should be		......1.312	"

The levels of the Y previous to its canalization were at Halfweg,

	Feet.
Mean high water	0.26+AP.
" low "	0.82−AP.
Maximum high water......	6.62+AP.
Minimum low "	3.94−AP.

After the closing of the Y, the canal which took its place was to be maintained in terms of the concession at 1.64−AP. This level remains simply a desideratum as far as Rhineland is concerned, while during the past year the mean level of the canal at Halfweg was 1.20−AP. The last pumping station was intended to control the internal levels, in which the difference of a few inches might cause incalculable damage; the maximum ought never to exceed 1.31 ft.—AP.

The Halfweg pumping station has six float-wheels, of a combined width of breast of 38.70 ft. The external diameter of one of the wheels is 23 ft., that of the other five, 21.33 ft.; the internal radius is 5.92 ft. The floats, twenty-four in number, are inclined to the radius, so as to be tangential to a circle concentric with the wheel, and having a radius of 2.85 ft.; the center of the wheel is at 5.6 ft.+AP. The steam-engine has four separate valves, with expansion regulated by hand (of the old double-acting Cornish type); the cylinder is 3.33 ft.×8.0 ft. There are three boilers always in steam, having each 538 square feet of heating surface. The maximum pressure is three atmospheres. The driving axle is connected by toothed gearing on each side to a shaft carrying three wheels; the speed is reduced in the ratio of 13.5 to 6; the wheels are all upon the same shaft, but this is not all in one piece, but in several, which can be coupled up as required.

There are three systems of construction of water-wheels, which differ in the method of transmitting the force. In the first system the force is transmitted by a driving axle and spokes acting as struts; in the second by a toothed wheel upon the circumference, the axle and spokes acting as struts; in the third, by a similar toothed wheel, but with a double set of rods in tension instead of spokes. The Dutch still adhere to the first system, although, according to Redtenbacher, it is not suitable when the power exceeds 10 or 12 H.P. With large wheels it is very heavy; thus, the Italian wheels at Bresega, near Adria, which are on the the third system, have an external diameter of 39.4 ft., an internal diameter of 26.25 ft., and a breadth of 6.56 ft.; there are no larger wheels than these either in Holland or Italy. The displacement of water is about 5.300 cubic feet per minute per wheel. The axle of these wheels has a diameter at the thickest

* In 1881, there were discharged from the boezem 21,825 millions of cubic feet of water, of which 12,537 millions were raised by machinery; 2,684 millions cubic feet were let into the boezem, the greater part in summer to supply the canals.

part of 1.41 foot, and 1.25 foot at the bearings. The wheels at Katwijk, which are on the first system, are only 29.5 ft. in diameter, yet the axles of the furthest wheels are of the same diameter as above.

At Zeeburg, near Amsterdam, there are eight wheels of the most recent construction, of 26 ft. 3 in. diameter, and 10 ft. 8 in. breast. The driving axles of the wheels furthest from the motor are 1 ft. 6 in. in diameter, and weigh over 6 tons; each wheel has four sets of spokes, each set weighing 4 tons; the driving axles nearest the motor weigh nearly double; there are 282 cubic feet of oak, and 222 cubic feet of pine timber in each wheel. Compared to the mass and weight of material, the volume of water raised, amounting to 7,063 cubic feet per minute per wheel, seems small. The velocity of the periphery is about 208 feet per minute, which in Holland is considered moderate, but in Italy high. In this system of construction the axle is subject both to bending and torsion; in the suspension system to bending only.

Mr. Zangirolami, of Adria, constructs wheels with curved buckets capable of raising water to $\frac{4}{5}$ of the radius, giving excellent results. Instead of two toothed wheels, one at each side of the wheel, he puts one toothed wheel in the middle, thus avoiding the practical difficulty and expense of two cogged wheels of precisely similar pattern on the one hand, and the twisting effect produced by a single cogged wheel when placed at one end of the wheel on the other.

At Halfweg the driving-axle is of cast-iron, solid, 1 foot 2 inches in diameter near the motor, and 10 inches at the further end, with enlargements at the joints. The framework of each wheel is formed of three sets of spokes, which are cast in one piece with the nave and ring, or rather each set is cast in two parts and bolted together. The whole weight of one wheel with its axle is probably about 15 tons.

Tables are given of the work performed by the wheels monthly during the years 1872–5. The first table gives the number of revolutions per minute, the number of hours worked, the volume of water raised, the lift, the effective HP., the consumption of coal in each month, and per HP. per hour. The second table shows how the duty of the engine increases with the lift. When the lift was from 8 inches to 1 foot, the consumption of coal per HP. per hour averaged 14.20 lbs.; when the lift was from 1 foot to 1 foot 4 inches the consumption averaged 11 lbs.; when the lift was from 1 foot 4 inches to 1 foot 8 inches, the consumption averaged 8.8 lbs., and when the lift was from 2 feet to 2 feet $3\frac{1}{2}$ inches, the consumption averaged 5.5 lbs. per HP. per hour.

This difference is accounted for by the large amount of power required simply to drive the wheels themselves. This being a constant quantity, is much greater in proportion when the work expended in raising the water is small. It would be useful to have experiments on the performance of the engines when simply turning the wheels, but, failing such experiments, the author gives instances in which the lift was very small. On the 16th of March, 1876, with a lift of only 0.45 of a foot, all the six wheels were at work for 495 minutes, and made 2,043 revolutions, the immersion of the wheels at the time being 3.75 feet on the low-water side. Applying the recognized coefficient for similar wheels of 0.90, the volume of water raised was estimated at 30,000 cubic feet per second. The useful effect was therefore 25 HP. The total consumption of coal was 10,493 lbs., or 50 lbs. per effective HP. per hour.

General Delprat investigated experimentally the working of a somewhat similar establishment with six paddle-wheels for eighty days, with lifts varying from 0.033 of a foot to 1.75 foot. He found that the useful effect, when the lift was a minimum, was only 3 HP., while the work corresponding to the *vis viva* of the water issuing from the wheel was 69.24 HP. With the maximum lift, on the other hand, the former was 130.05 HP., the latter only 19.57 HP. The sum of the two kinds of work, useful effect, and work corresponding to the velocity, was 72.24 HP., with the lift of 0.033 of a foot, and 149.62 with the lift of 1.75 foot. This sum rather more than doubled, while the lift in the last case was fifty-three times that in the first, and the useful effect in water raised was about forty-three times as great.

These wheels, therefore, besides being very costly, have the disadvantage that, as the inner water-level diminishes the

discharge also diminishes, while the number of revolutions remains constant. If, then, this reduction in the inner water-level is accompanied with a reduction of the lift, the conditions of useful effect are still worse. The six wheels at Halfweg, which with an inner water-level of 8 inches—AP (the highest), give a discharge of 8,263 cubic feet per revolution, give only 5,510 when the water is at its lowest level of 2.46 feet—AP.

Hydraulic Station at Katwijk.—This was erected in 1880 to regulate more completely the waters of the Boezem. The levels of the external water are:—

	Feet.
Mean high water	2 93+AP.
" low "	2.72—AP.
Maximum high water	11.48+AP.
Minimum low "	6.56—AP.

The distance of the buildings from the sea is 2,000 feet.

This station and that at Zeeburg, near Amsterdam, intended for changing the water in the canals in that city, are the two largest of recent construction in Holland. In both the system adopted is similar to that at Halfweg. At Katwijk there are six wheels, each 29 feet 6 inches in external diameter, and 8 feet breast. The centers of the wheels are at 8 feet 3 inches above AP., the sill of the channel is at 1.64 foot—AP., which is the mean level of the surface of the internal water. The number of wheels at work can be regulated by gearing. The weight of a single wheel with its axle is estimated at 41½ tons. The selection of this system shows that it is considered the one best adapted to the conditions at Katwijk. Flat buckets have been adopted as being the best under the conditions, namely, a lift varying daily (with respect to sea-level), and averaging from 0 to 4.5 feet, with an ordinary maximum of 6.89; the fluctuation of the internal level being very slight, the greatest difference in the year 1881 being 1.60 foot, and the greatest in a month being 0.82 foot. There is no doubt that the differences will be still smaller with the new lifting wheels at work. The manner in which the variations in internal water-level are kept within very small limits is one of the remarkable features in the Dutch system.

The buckets of the wheels at Katwijk are tangential to a circle concentric with the wheel, and having a radius of 5.25 feet. The effect of this is that with the internal water at its mean level, and the external at mean high-water level, the angle of ingress is about 20° 30′, and that of egress 42°. The proper diameter of this tangential circumference is a subject much discussed among Dutch engineers. This, together with the radius of the wheel, and the position of the axis, determines the angles of ingress and egress, upon which the effect of the wheel greatly depends. Inspector J. A. Beijerinck, the celebrated engineer of the Zuidplas and Haarlem reclamations, and the author of the first really practical project for reclaiming the Zuider Zee, has devoted considerable attention to float-wheels and screw-elevators in a monograph on the Zuidplas, which will be referred to later on. He upholds the rule that the angles of ingress and egress of the paddles with the mean internal and external water-levels should be equal; which, when the radius of the wheel is known, readily gives that of the circumference to which the paddles are tangential, by means of a simple geometrical construction. This has long been a general practical rule, and is still frequently followed, though the desire for innovation has given rise to others, perhaps too many.

If α is the angle of ingress, β that of egress, H_i H_e the depths below the axis of the wheel of the internal and external levels, $\triangle$ the lift, R the radius of the wheel, ρ that of the above-named circumference, we have

$$H_i = R\left(\sin\alpha\sqrt{1-\frac{\rho^2}{R^2}}+\cos\alpha\frac{\rho}{R}\right)$$

$$H_e = R\left(\sin\beta\sqrt{1-\frac{\rho^2}{R^2}}-\cos\beta\frac{\rho}{R}\right)$$

$$\triangle = \sqrt{R^2-\rho^2}\,(\sin\alpha-\sin\beta) + \rho\,(\cos\alpha+\cos\beta).$$

Of the quantities H_i, H_e, R, α, β, ρ, any three can be found when the other three are known, according to the theory of hydraulic wheels, by equations which correspond to the minimum for the loss of work due to various causes. This loss being expressed in terms of the remaining independent variables, including in these the velocity, which is another very important element, there will be enough equations to determine all the unknown qualities. In practice they are given by rules. One is that already given, from which

$\triangle = 2\rho \cos. \alpha$. Some authorities make it a rule that the value of α shall lie between 20° and 30°. Since, if the immersion i of the buckets is known, $R = H_i + i$, the value of R depends upon that of i, which is generally beetwen 3.25 feet, and 4.87 feet, according to the difficulties of foundations and construction. Some maintain that the ratio $\frac{\rho}{R}$ must lie between $\frac{1}{3.5}$ and $\frac{1}{4}$. Others state that H_e must lie between $\frac{1}{7}$ and $\frac{1}{5}$ of R, but the principal rule, and that most generally adopted. is that of the equality of α and β. At Katwijk, however, this rule has not been adopted. At the maximum daily level the angle of egress is nearly double that of ingress, which is 20° 30′. At the mean level it is more favorable, increasing by about 6°. There seems very good reason for departing from the established rule.

It is true, indeed, that by improving the ingress the egress suffers, but in a very different degree. R being given, α and β can be expresssed by a single variable, the angle Φ of the paddle with the radius. The loss at the ingress will be a certain function f_i (Φ), that at the egress f_e (Φ), indicating by f_i and f two different functions. The variable Φ will be determined by the condition that $f_i(\Phi) + f_e(\Phi)$ shall be a minimum. It would be difficult and almost useless to determine mathematically the expression of that sum as a function of (Φ). It is certain that for a given variation of Φ the gain on one hand is very different from the loss on the other, and that it is better to increase the angle of egress. If this is too small, there is a useless heaping up at the discharge, which may be a very considerable part of the lift, or may even exceed it, and the rule of equal angles often places the wheels under unfavorable conditions.

The Katwijk wheels are driven by two compound engines supplied with steam from eight Lancashire boilers, with double fire-boxes, each 32.8 feet × 7.31 feet, with seven Galloway tubes. The heating-surface of each boiler is 970 square feet. It was specified that with a working pressure of 5 atmospheres the eight wheels should raise—

				Feet.
4,238,000	cubic feet per hour	with a	lift of	4.10
3,532,000	"	"	"	5.27
2,825,000	"	"	"	6.88

so that the maximum useful effect should be 615 H.P.

On the trial of the engines, the number of revolutions varied from 3.93 to 4.54 per minute. The most convenient for ordinary working is 4, corresponding to 36 revolutions of the fly-wheel, the velocity at the periphery being 7.22 feet per second. The ratio of useful effect to indicated power varied from 33 to 70 per cent., the average being 50. It is expected that a higher value will be obtained after the engines have been in use a little while, and the gearing has become eased.

The principal dimensions of the buildings are:

	Ft.	Ins.		Ft.	Ins.
Engine-house, inside...........	59	0	×	49	3
Boiler " "	93	8	×	65	3
Each of the covered chambers for the wheels....................	44	9	×	39	4
There are two chmneys 85 ft. high above the fire-grates, with an internal diameter of....	6	3			
Coal-store..........................	164	0	×	32	9

The cost of the establishment, exclusive of earthwork in the canals, was

	£.
For the buildings, about......	15,000
" machinery "	14,200
Total...............	£29,300

Pumping Station at Gouda.—The external water-levels (of the Yssel) are—

	Feet.
Mean high water......	3.64+AP.
" low "	0.55−AP.
Maximum high water.........	10.06+AP.
Minimum low "	4.26−AP.

When the station was established, in 1857, six paddle-wheels were erected, which in 1872 were changed to wheel-pumps, of which the axis was at 7.21 feet +AP, the lowest part of the drum at 2.50−AP, that of the buckets 5.78 feet −AP. The total available width of breast was 31.17 feet. In 1873 two of the buckets, of which there were only six, broke, and in repairing them the number was increased to twelve. Under the direction of Professor Henket the buckets were made of a curved form, with the concavity towards the inner water. Since then repairs have been effected by Mr. Rijk, who introduced curves with the concavity towards the outer water, the curvature being that of a logarithmic spiral. At one time three varieties of buckets were in use at the same time on these wheels, three having Mr. Rijk's

form, one that of Professor Henket, two nearly flat. It was evident that the difference in the delivery was slight; Rijk's system was on the whole preferable.

The steam-engine here is of the same class as that at Halfweg. The cylinder is 3.65 feet × 8 feet. There are three Cornish boilers, each having 883 square feet of heating surface. A table is given showing the performance of the engines during the year 1877, from which it appears that, omitting the months of January, April, and May, when very little work was done, and the lift was small, the consumption of coal was 8.6 lbs. per HP. per hour. Under the same circumstances the Halfweg engines and wheels would have given much better results. In the calculation, the loss of water by slipping and by the partial filling of the buckets, was taken at 15 per cent., which is too little. Some experiments gave 22 per cent. for this loss.

General Association of Delfland.—The total area of Delfland, which ranks next in importance to Rhineland, is over 74,000 acres. Its boezem* is relatively very small, about 954 acres. Its conditions in regard to drainage have always been, and still are, worse than those of Rhineland. Besides the small area of the boezem, the natural discharge into the rivers is attended with difficulty, and there was no artificial means of discharge until 1864, when a station was established at Vijfsluizen, upon the Meuse, not far from Schiedam.

The levels are as follows, referred to the Delfland datum, D. P., which corresponds to 1.071 foot below AP.:—

Internal waters	Minimum	0.82−DP.
	Maximum	0.66+DP.
External waters	Mean daily high water	4.00+DP.
	" low "	0.07+DP.
	Max. high water, about	7.02+DP.
	Min. low " "	1.74−DP.

The water is discharged naturally whenever the levels admit. There are six wheels, disposed symmetrically with respect to the motor, of 26.24 feet external, and 12.47 feet internal diameter. The width of breast is 4.92 feet. They work up to 5.38 + DP. The axis is at 8.35 + DP. The radius of the tangential circle is 2.75 feet. The system of construction is similar to that at Halfweg. The engine has a single cylinder 3 ft. 4 in. × 8 ft. 3 in.; the ratio of transmission is 11 : 4.4. The normal velocity of the wheels is 4.4 revolutions per minute. There are three Cornish boilers, 33 ft. × 6 ft. 6 in.; the maximum pressure is 3 atmospheres.

A serious defect in the action of float-wheels is the great diminution in discharging power as the internal water lowers. At Vijfsluizen, for instance, with the inner water-levels at 0.66 − DP, zero, and 0.66 + DP, the volumes of water discharged are respectively 1,092, 481, 1,263,133, and 1,421,845 cubic feet, that is to say, that the volume varies from 3 to 4 for the above limits of water-level. The following are the results of two years' working. The year is reckoned from the 1st of May:—

1874–5.—Total number of hours worked, 807. On only thirteen days was water raised continuously during twenty-four hours. The longest stretch of work was 120 hours. The engines were worked so as always to give a useful effect of 104 HP. The consumption of coal was 7.075 lbs. per HP. per hour, including that used for getting up steam and banking the fires while the engines stopped for short periods.

1876–7.—Number of hours in work, 2,086. Continuous work throughout the twenty-four hours on twenty-eight days. Consumption of coal 6.90 lbs. per HP. per hour.

These results, though deserving of record, are not entirely trustworthy, as

* Both as regards the internal waters in the dykes and canals, and the external waters in the boezems, the conditions are usually expressed by the ratio between the water-surface at the normal level and that of the whole polder in the former case, and that of the entire group of polders forming a general association in the latter. Thus the water-surface of the boezem of Delfland is $\frac{1}{77}$. Each of the separate polders has its own ratio to the internal waters. These two ratios are quite distinct, and express relations which for new undertakings are determined by very different standards. In the case of the polders the ratio depends upon the power of the water-raising machinery, in that of the boezems, upon the régime of the discharge into natural receivers, rivers or sea, subject to tidal action. When wind was the only motive power, this sufficed to drain the polders, but not as a rule the boezems. For them, therefore, the ratio depended generally solely upon the régime of the natural receivers, upon the duration and extent of the ebb tide, and upon the maximum heights which could be given to the banks of the canals belonging to the boezems. For the polders, therefore, the works had to be so arranged that with the ordinary winds, taking into account periods of calm, the land could be kept as far as possible from submersion. The wind-mills had to stop working when the wind failed, and also whenever the water-level in the boezem attained a dangerously high level. With the introduction of steam all these relations were naturally changed. In the case of the boezems the regimen of the receivers still remains a most important consideration, as the greater part of the water must be discharged by natural means.

they are founded upon the hypothesis that the useful effect is constant.

Mastenbroek Polder.—This pumping-station is interesting from the fact that in 1878 three wheel-pumps were erected there, which had been very carefully studied by two engineers of very high standing, Professor Henket and Mr. Backer. These engineers studied the subject with reference to both float-wheels and wheel-pumps, and left the choice to the constructors, the work being let by tender.

These wrought-iron wheel-pumps were of a very different form from that proposed by the original inventor. The specification stated that the diameter of the drum was to be 16.40 feet, two were to be 3.61 feet breast, the third 7.87 feet; the external diameter was to be 23.61 feet, there were to be twenty buckets of the form adopted by Rijk at Gouda, with concavity towards the outer water. The lowest point of the drum was to be at the highest internal water-level. The axis was to be at 5.90 + AP, and the extreme internal and external water-levels 1.47 — AP and 5.92 + AP respectively. The idea of the engineers was to take advantage of the experience obtained at Gouda, and to produce a perfected float-wheel. The play between the buckets and the walls was reduced to a minimum by fastening strips of wood to the edges of the former. The useful effect was prescribed as under:—

Lift.	Expansion of Steam.	No. of Revolutions per Minute.	Discharge.	Useful Effect.	Number of Wheels in Action.
Feet.			Cubic feet.	H.P.	
2.80	$\frac{6}{7}$	5.15	15,892	85	3
6.56	$\frac{4}{5}$	4 19	6,745	85	1 (the large one)

It was specified that upon the completion of the work there were to be two trials, one carried out by the drivers and stokers of the constructors, the other by those of the association under the direction of the former. The positions of the water-gauges (a frequent cause of dispute) were definitely fixed, that for the internal water at 39.4 feet from the axis of the wheels, the other at 26.25 feet. The second trial was to last for thirty days during the three months in which the constructor was to be responsible for maintenance. In the event of the consumption of coal exceeding that guaranteed by the contract, the contractor was to pay three-fourths of the capital sum which would have to be paid by the association to provide the additional coal.

There were nine tenders for the work, as under, the names being suppressed.

No. of Tender.	Price for Wheel-Pumps.	Price for Float-Wheels.	Maximum Consumption of Coal in lbs. per H.P. per Hour guaranteed.			
			Wheel-Pumps.		Float-Wheels.	
			Lift, 4.26 feet.	Lift, 6.56 feet.	Lift, 4.26 feet.	Lift, 6.56 feet.
	£.	£.				
1	4,831	4,792	6.06	6 06	6.50	6.50
2	5,290	5,290	4.84	4.84	4.84	4.84
3	5,078	5,078	4.84	4.84	4 84	4.84
4	5,375	5,375	5.50	4.95	5.50	5.50
5	6,037	6,262	6.83	6.83	6.83	6 83
6	6,230	6,490	7.40	6.45	7.40	6.45
7	6,361	6,563	6.61	6.61	6 61	6.61
8	6,138	6,338	6.61	6.61	6 61	6.61
9	8,125	8,500	5.72	5 72	5.72	5.72

The tenders were from first-rate constructors, Dutch, German, and English, and are interesting as showing their judgment upon the two systems proposed by the engineers. The prices included the whole of the machinery, with boilers, &c., complete. The contract was let to No. 1, at the rate of £57 per HP. The cost of the buildings was £7,166.

The power was transmitted through the axles of the wheels. The ventilation of these wheel-pumps was not satisfactory, though the question had been carefully considered.

The principal dimensions of the engines were: Cylinder 2.3 feet×4 feet; capacity of the condenser, one-third that of the cylinder; diameter of fly-wheel, 16.40 feet, and its weight 7.38 tons; ratio of transmission, 7.81 to 1. The three boilers were of the Cornish type, 28 ft. 9 in. ×4 ft.

When the author visited the works they had been so short a time in operation that the consumption of coal could not be accurately ascertained, but it appeared that it would be about that of the best engines for water-lifting in Holland, namely, slightly more than 6.6 lbs. per HP. per hour. He considers that the opinion of the engineers is justified, that wheel-pumps and float-wheels are about equally good.

The engine-house is 46.50 feet long, and 18 feet broad. The boiler-house (for three boilers) is 46 feet long, and 27.5 feet broad. The chimney is 78.75 feet high above the fire-grate. Its section increases towards the top, the internal diameter being 3.60 feet at the bottom, and 4.60 feet at the top.

Zuidplas.—This deep lake owed its origin to the extraction of peat. It is not known when this extraction commenced, but there are legal regulations upon the subject as far back as the year 1595. At the beginning of the present century, windmills driving float-wheels were erected to keep down the level of the water in the lake, and in 1825 the Government determined to drain it altogether. The normal level of the water was fixed at 18.40 feet—AP. The highest level in the Yssel, into which the water had to be discharged, was 3.38 feet+AP. The total lift was, therefore, 21.78 feet, and it was decided to divide this into two distinct lifts, each of which was again subdivided into two parts.

The first principal lift was from the low-lands to a canal, which was carried round the lake at a certain level. From this canal the water was raised to a collecting basin, and thence discharged into the river by sluices. In this way the basin acted also as a regulator to the river, which is subject to great fluctuations of high and low water in times of flood. These regulating works had to be of much larger capacity in those days, when the motive-power was wind, than would now be necessary. The normal water-level in the circumscribing canal was fixed at 13.38 feet above summer level.

The lift was divided into two parts of 6.69 feet each, and the method adopted was that of Archimedean screws, driven by eleven pairs of windmills. From the canal to the river the water was raised in two lifts by means of float-wheels, the lower worked by seven, the upper by five windmills, a part of the discharge into the river being by gravitation at low tide. This arrangement was, however, modified by the introduction of two steam-engines, of 30 HP. (actual) each. These were attached to a couple of screws, which performed the whole lift of (in their case) 22.18 feet at once. The erection of these engines marks an era in the history of drainage. Although the first attempts at using steam-power were made in 1776, near Rotterdam, the only practical application had been made at Arkelschendam, and as these consumed 31 lbs. of coal per HP. per hour, it was thought that steam could not be used economically. The Zuidplas engines consumed 22 lbs. per HP. per hour, which in those days was not considered bad, and led to the adoption of steam for the Haarlem reclamation.

The thirty windmills and the two steam-engines emptied the lake in 1840, and kept it dry. They were all in action up to 1871. Each windmill, with its screw, raised the water from 2,352 acres to a height of 3.28 feet. Each wind-mill, with its float-wheel, raised that from 1,898 acres for the first half of the upper lift to a similar height, and from 2,656 for the second half. The annual cost of maintaining these thirty mills was very

high, amounting to about £1,800, or about £60 per mill.

In the meantime the cost and working expenses of steam-engines have been much reduced, while improvements in agriculture require a more perfect regulation of the water-levels, and for these reasons steam has been gradually substituted for wind-power. In 1871 ten mills were removed, and in 1873 it was decided to replace the remaining twenty by steam. A Commission of two well-known engineers was appointed, to whom the following questions were proposed:—

I. What is the best machine for raising 7,240,000 cubic feet of water per twenty-four hours, to a height varying between 11.3 feet and 12.3 feet?

II. When the height varies between 4.9 and 13.1 feet?

III. What is the best system of engines and boilers?

IV. What is the estimated expense?

The answer of the Commission to the second question was decisive: "Centrifugal pumps. No other machine applies so well to differences of level in the external and internal water. No other permits the application upon so large a scale of the whole disposable motive force to all lifts comprised within the limits stated.

"The machine adapted for the maximum lift will, with lower lifts, discharge proportionally larger volumes; while the useful effect which is produced by the coal consumed, does not vary to any great extent."

These statements of the Commission went rather too far. The duty is anything but constant,* and while it is quite true that centrifugals adapt themselves more readily to differences of lift, and are available for much higher lifts than float-wheels, they have this disadvantage, which the Commission failed to point out, namely, that there exists in each case a minimum velocity, below which they will not raise a drop of water, whereas wheels, piston-pumps, screws, &c., if working at all, always discharge water.

In reference to the first question, the Commission could not say that one form of pump was superior to all others for a high, but nearly constant lift, and they therefore recommend that as centrifugal pumps should be adopted for the second, they should also be adopted for the first case, as they consider them as good as any other form for the purpose, and by having the whole of the machinery from the same firm there would be a saving in cost.

The selection of centrifugal pumps was subject to certain conditions. They were to be direct-acting, the disks to be above the internal water-level, and the delivery-pipe was to be carried by a bend below the low-water level of the external water, so that the lift would vary with that level. Each pumping-station was to have two centrifugal pumps (Gwynne's pattern), driven by separate non-compound direct-acting engines, capable of raising 2,542 cubic feet of water each per minute. The diameter of the disk was to be not less than 6 feet, and the velocity one hundred revolutions per minute. The suction and delivery-pipes were to be at least 3 feet in diameter. The lower station was to have four, the upper three, Lancashire boilers, 25 feet × 6.5 feet, with twenty-four Galloway tubes. The maximum consumption of coal was to be 6.61 lbs. per HP. per hour, with lifts varying from 5 to 13 feet.

The recommendations of the Commission were adopted, and in 1876 the new machines were set to work.

Tables are given of the performances of the machinery, but before discussing them the author makes some observations upon the float-wheels adopted. For the lift of 11.8 feet, the diameter of wheel is 32.8 feet, which is believed to be the largest in Holland, though similar wheels, of a larger diameter, are used in Italy. Mr. Forster gives a formula for calculating the diameter as follows: Given i, the immersion of the paddles, p the lift, then the diameter $D = 9.82\sqrt{i+p} = 9.82\sqrt{H}$, in which H = the height from the lowest point of the wheel to the highest external level to which the water has to be raised, the measurements being in feet.

The Dutch use smaller diameters, part-

* Mr. Backer, one of the commissioners, has since expressed another opinion founded upon his later experience ("Rapport over den Waterstaatstoestand"), that the consumption of good coal per HP. per hour for centrifugal pumps when working at their full power varies with the lift, and is, for lifts of 7.2 feet, 6.6 lbs.; for lifts of 1 foot, 2.4 feet; and from 3.3 feet to 5.3 feet, 9.37 lbs., 8.82 lbs., and 7.71 lbs. respectively, not counting the coal required for getting up steam, which he puts at 4 per cent. in his own case, but which ies with the number of interruptions to the work.

ly on account of the great weight of their wheels, partly from being accustomed to wind-power, for which they are more suitable. At Katwijk, where the wheels of most recent construction have a lift varying from 12.14 feet to 13.17 feet, the diameter is only 31.17 feet, while, according to the Italian custom, the diameter of the lowest lift should be 39.6 feet. At Zuidplas, $i = 3.28$ feet, $p = 11.8$. D should therefore, by the Italian rule, be 38 feet. It is only 32.8 feet. It should be observed, however, that the Katwijk wheels are similar to those used in Italy, but those at Zuidplas have curved paddles, on Korevaar's system, and for this reason the diameter is less than it otherwise would be, as also is the immersion. For this type the inventor gives $D = 2H$ as the minimum diameter.

The author has several times seen the Zuidplas wheels at work. When the levels are favorable the wheel enters the water well, meeting it with the edge of the float; but the lower wheel, which has a high lift, does not leave the water as it should, but throws it to an unnecessary height. The upper wheel, however, with a lift of 8.20 feet, acts better. For the lower, the diameter of 32.8 feet is too little for the lift of 11.8 feet, notwithstanding the curvature of the paddles. This curvature, which is concave towards the internal water, has a disadvantage attending it, that when the level of the internal water lowers to such a depth that the convex surface, instead of the edge of the paddle, strikes the water, it drives the water backwards to a certain extent, instead of carrying it forwards.

The author now refers to the actual results of the working of the various machines at Zuidplas. There is this notable feature about the works, that there are two pairs of pumping-stations, with machines of two different types, while those of one pair are identical in construction, and work under different conditions as to lift. The volume of water discharged may be taken as constant for each pair. The Tables show that neither with paddle-wheels nor with centrifugal pumps is the consumption of coal proportional to the lift, or to the work done. In the case of the wheels, the contract specified that the actual H.P. should be 90 each, and the total consumption of coal (Ruhr of the first quality) should not exceed 595 lbs. per hour with any ordinary lift, with a penalty or premium of £1 13*s.* for each 2.2 lbs. over or under 595. It is hardly necessary to observe that the trial proved satisfactory and obtained a premium. In practice, however, the upper wheel especially was far from satisfying these conditions. The lower wheel, though apparently working under much less favorable conditions than the upper, gives a considerably better effect, owing to the fact that with these wheels the effect increases rapidly with the lift. The weight of each wheel, with its axle, is not less than 21 tons. The velocity of periphery is about 6.5 feet per second. The actual discharge of these wheels is 92 per cent. of the theoretical. It amounts to 3960 cubic feet per minute for each wheel, and the lift being 11 feet 9 inches, the actual H.P. is 89. The consumption of coal in ordinary working is 7 lbs. per H.P. per hour.

It should be observed that while the wheels very frequently worked day and night, the centrifugal worked generally at intervals, and sometimes for very short periods, as, whenever the state of the tide permitted, the water was simply discharged by gravity through sluices, but the boilers were nevertheless kept in steam, and the consumption of coal reduced to pounds per HP. per hour, is no doubt greater than it would have been had the pumps been working continuously. The tables given in the Paper show that the duty of the wheels was somewhat better than that of the pumps, but no doubt this is partly accounted for by the above circumstance. In these pumps the power measured by the water raised varies from 40 to 49.7 per cent. of the indicated HP., and the consumption of coal is 7.67 lbs. per actual HP. per hour.

In one respect, however, the wheels are decidedly more economical, namely, the consumption of lubricants. An inspection of the books for 1877 shows that the consumption per HP. per hour was—

	Pint.
For the wheels	0.0053
" centrifugals	0.0123

The principal dimensions of the buildings are.

For the float-wheels—

	Ft.
Outside length of engine and boiler-house	69
" width of engine-house	37
" " boiler-house	40

For the centrifugals—

	Feet.
Internal dimensions of room for two pumps	33×28
Internal dimensions of boiler-house	36×42
Coal store (not roofed)	98×66
Engine driver's house	33×27

The two steam-engines, with the two wheels of 32.8 feet diameter, and another, not working, of 16.4 feet diameter, cost £5,000, or per HP. £28.

The four centrifugals, with engines and boilers, cost £11,833, or per HP £46.

The cost of the buildings is not given. Mr. Korevaar says that the cost in pounds of float-wheels, including all machinery and buildings complete is $666 + 66\ k$, in which k is the horse-power. This rule applies to all powers between 6 and 100.

Bullewijker-polder.—At this polder very careful experiments have been made by the engineer, Mr. Elink Sterk, upon the performances of the centrifugal pumps supplied by Messrs. J. and H. Gwynne, of which the following are the dimensions:—

	Ft.	In.
Diameter of steam-cylinder	1	8
Stroke	1	6
Diameter of the disk of the centrifugal pump	5	7
Width of blades at the periphery	0	5½
Angle of the blades at the periphery	17°	
" " " axis	90°	
Diameter of the suction and delivery pipes	2	6

	£.
Cost of engine, pump and one boiler (heating-surface 743 square feet)	2,154
Cost of reserve boiler	472
Total cost	2,626

This is exclusive of erection, and of suction and delivery pipes.

OBSERVATIONS ON THE CONSUMPTION OF COAL.

Lift from ....14.3 feet to 15.3 ft.
Discharge per second, maximum........... 41.8 cu. ft. per second.
Discharge per second, minimum..............32.5 cu. ft. per second.
Discharge per second, mean..................36.0 cu. ft. per second.
Mean effective H.P.....62.219 " "
Consumption of Westphalian coal during the experiments, which lasted $6\frac{1}{20}$ hrs. } 1,938 lbs., or 5.22 lbs. per H.P. per hour.
Number of revolutions, from..................134.4 to 136.5
Pressure in boiler, from 66 to 76 lbs.

EXPERIMENTS WITH THE INDICATOR.

Pressure in boiler....71 lbs.
Introduction, from..10 to 14 per cent.
Vacuum in condenser.25½ inches.
Revolutions per minute...............135.8
Indicated H.P......117.7
Discharge per second, from..............40.26 cu. ft. to 40.64 cu. ft.
Lift................14.5 feet.
Effective H.P.......68.57 to 69.07
Ratio of effective to indicated H.P. from 0.583 to 0.587

In these experiments the water was measured very accurately. The results are the more satisfactory because the suction and delivery pipes were unusually long, 49 and 85 feet respectively. These pipes are not of constant diameter, but diminish as they approach the pumps.

It appears that in Italy centrifugal pumps have been discredited, owing to unsatisfactory results obtained from a set erected at Codigoro in 1874 by Messrs. J. and H. Gwynne, and the author is desirous of pointing out the great improvements effected since that date.

North Sea Canal.—In order to regulate the level of this canal, which receives the waters of very extensive boezems, and of the polders formed upon the bed of the Y, the company have been obliged to erect several pumping-stations, of which the principal is that of Schellingwoude, near Amsterdam. A peculiarity of these pumping-stations is the application of Appold's turbine pumps, which the author describes.

The results were by no means satisfactory, the consumption of coal being not less than 11 lbs., but it is to be noted that the actual quantity of water raised was in excess of that for which the engines were designed, and it was upon this latter that the calculations were made; also that the lift was less than was expected, which would partly account for the excessive consumption. These turbines, in consequence of these results, are now never used.

Turbine pumps on a very small scale are used for draining small areas of about 75 acres, with lifts of less than 1 foot 6 inches. They are made of wood, and driven by wind power. They occupy a space of 4 feet by 4 feet, and cost between £16 and £25.

Except in this diminutive scale turbine pumps are not now in request in Holland.

In Italy on the other hand they are said to answer well.

City of Rotterdam.—Rotterdam has three pumping-stations with machinery of an entirely different character to any of those previously described. Their use is to regulate the water-level in the suburban part of the town called Polderstad. They discharge water into the Meuse, and also introduce fresh water from the river into the canals. The canals are greatly polluted by sewage matter.

There are three pumping-stations, two of which are provided with lift and force pumps, the third with a Fijnje's pump,* which is driven by an engine with a cylinder 2.75 feet×6.89, the size of the pump being 6 feet×4.92 feet. The cost of the whole machinery was £4,166, or £104 per HP.

A table is given, showing the performance and duty of this and the other two pumps at Rotterdam.

Fijnje's pumps are very simple, but have the disadvantage of requiring deep foundations.

Haarlem Lake.—A description of Dutch pumping machinery would be in complete if no mention were made of the three pumping-stations which have dried up and keep drained the former lake of Haarlem, covering an area of 44,480 acres. The emptying of the lake was begun in 1849 and finished in 1852. A table prepared by the engineers, Mr. Van de Poll and Mr. Elink Sterk, is given, showing the performance of the engines at the three stations, Cruqius, Lijnden, and Leeghwater. The dimensions of these machines are:—At Leeghwater, engine cylinders, small, 7 feet, large, 12 feet diameter, stroke 9.3 feet; pumps, 11 in number, diameter 5.25 feet, stroke 9.3 feet. At Cruqius and Lijnden, the diameters of the cylinders as above, stroke, 8.86 feet; pumps, 11 in number, diameter, 6 feet, stroke, 8.86 feet Ratio of the effective to the calculated discharge (at the normal velocity), for Leeghwater about 84 per cent. (this is somewhat doubtful), for Cruqius 89 per cent. (this figure is reliable). The consumption of coal as found by records extending over a considerable time is 6.83 lbs. per HP. per hour.

Mr. Sterk made some experiments with a view to ascertain the difference in working at the normal speed of about 7 strokes per minute, and when this was reduced to 3 strokes. With seven pumps at work, he found that in the latter case the indicated HP. was 192, the effective 134 HP., or 0.698 of that indicated. The consumption of coal was 5.44 lbs. per indicated, and 7.80 lbs. per effective HP. per hour. When working 7 strokes per minute, the indicated HP. was 492, the effective 361, the consumption of coal 4.94 lbs. per indicated, and 6.74 lbs. per effective, HP. per hour.

The coefficient of useful effect of the pumps is higher than that of any other machines in Holland; that of the motors on the other hand is small, and the consumption of coal per indicated HP. per hour is more than double that of good modern engines.

Comparative Notes upon the Various Systems.—Besides those described, various other hydraulic machines are in use in Holland, notably a species of Archimedean screw, which is very simple in construction and easily erected. It is well adapted for working by wind-power, and is a most useful machine for lifts which are too high for wheels. It requires, however, that the level of the external water should be nearly constant.

From analytical investigation, and from experiments carried out under certain conditions, it would appear that the best hydraulic machines are piston-pumps, and the worst centrifugals. Notwithstanding this fact, however, it is certain that in Holland, where pumping-machinery is used to such a very large extent, centrifugal pumps are preferred, and piston-pumps are the least used. In all pumping-machinery the duty varies greatly with the lift; this is recognized by the makers of centrifugals, so that in recent contracts at least three conditions of lift are specified, and for each the consumption of coal per HP. per hour is fixed. In the opinion of one of the principal Dutch authorities, the mechanical effect differs much less than is imagined between different classes of machines, and in designing a new establishment the greatest importance should be attached to other circumstances; such as the turbidity of

* These pumps were first used in Holland in 1847. They have since been introduced into Germany, and lately into America, where, owing to their success at the Philadelphia Exhibition, they have been applied on a large scale at several places.

the water, the probability of the internal water-level being permanently lowered in time, the nature of the foundations, the method of establishing communication between the inner and outer water, the level at which the machine can be placed with reference to the water to be discharged, upon which depends to a greater or less extent the facility of superintending and repairing the machinery, the security against inundations, the frequency of frost, &c.; also the cost of erection and working.

When flood-water conveying a large amount of *débris* has to be raised, piston-pumps are unsuitable, as they are liable to be damaged, and to have their valves choked. Centrifugals are better in such cases, but wheels are the best, and they have the further advantage that they can be easily repaired by ordinary workmen. The motors may be of common types, the only difficulty being that of adapting them to low velocities. With a diameter of 30 feet for instance the wheel must not make more than four and a half revolutions per minute, and with a single system of gearing the speed of the engines would have to be limited, for, with an ordinary speed of 70 strokes per minute, the ratio of transmission would be $\frac{1}{15.5}$, which is too high. On the other hand the tendency is to construct engines to work at high speeds, as being more economical.

Again, the system of direct action between engine and pump is the one which is most economical in fuel, but here the difficulty is that too high a velocity is required; for instance, at Legmeer, the engine makes 168 strokes per minute.

In regard to foundations, wheels are at a disadvantage compared to centrifugals, for, with a high lift the wheel must have a large diameter, the sill must have a low level, and this necessitates massive and deep masonry. In some cases this question of foundations is a very important one, and would determine the kind of machinery employed.

Another important point is the liability of the internal water to have its level permanently lowered. With machines in which the water is conducted to the pump by pipes, additional lengths can always be added to the piping, and the only difference is that the consumption of steam will be greater, but with wheels, screws, and possibly with force-pumps, a lowering of the level of the water would require costly alterations.

It is well known that such alterations of level occur in draining marsh-lands, and their amount varies with the nature of the soil; their extent is small in the case of sand, larger in clay, and greatest in muddy ground.

In regard to the separation between internal and external waters, the easiest and safest arrangement is that of pumps which discharge the water through pipes which are inserted in masonry walls of sufficient thickness. With wheels and screws much larger apertures are required, and these must be protected by strong sluices.

The Dutch hydraulic authorities state as general principles that for lifts above 16 feet 6 inches, wheels cannot be used, as their diameter would be too great. When the level of the external water is subject to great fluctuations screws cannot be used, as the amount of fluctuation allowable depends upon the radius of the screw, which cannot be more than 4 feet. When the water is very turbid, valve pumps are inadmissible; for moderate lifts, particularly when pretty constant, they recommend float-wheels, if for no other reason, on account of their simplicity and well-known durability.

It may be stated in general, that the useful effect of every machine varies greatly with the lift, and that in estimating the consumption of fuel, it is not enough to take the mean ordinary lift, but the variations must be studied and grouped together, the consumption due to each lift per HP. per hour must be computed from the results of existing machines.

The following table shows the number of pumping machines of different types erected in Holland in the years 1875 to 1881:—

(See table on page 295.)

The author concludes from the result of his investigations that no general rule can be given as the employment of one or other of the different machines, but that all the circumstances of each case must be considered before a decision is come to as to what machine to use.

	1875.	1876.	1877.	1878.	1879.	1880.	1881.	Totals
Float-wheels	3	1	1	4	12	9	8	38
Centrifugal pumps	1	1	6	6	11	9	16	50
Float-wheels and centrifugal pumps, combined	—	—	—	1	—	1	1	3
Wheel-pumps	—	—	—	1	—	1	—	2
Screws	3	1	7	2	12	4	1	30
Piston-pumps	—	—	1	1	—	—	2	4
Various	3	—	2	6	—	1	—	12
Totals for each year	10	3	17	21	35	25	28	139

APPENDIX.

While the proofs of the last sheets were being revised by the author, he received a copy of the "Tijdschrift" of the Dutch Institution of Engineers, containing a paper by Mr. Korevaar, entitled, "What are the most suitable machines for keeping polders drained?"

Though Mr. Korevaar does not in all cases agree with the author's conclusions, the latter sees no sufficient reason for changing his opinions.

Mr. Korevaar begins by saying that the only machines which deserve discussion are float-wheels, wheel-pumps, suction-pumps, lift and force-pumps, and centrifugals. He considers that all are effective when rightly proportioned, and that the first outlay does not differ much between them. The real point to be considered is the expense of working, and he endeavors to ascertain what are the most economical in this respect. But first he gives certain rules as to the discharge and lift suitable to each class of machines.

Float-wheels are capable of discharging 8800 cubic feet per minute, and have the advantage that they can be worked at any lift up to the maximum for which they are designed without any useless raising of the water. They will work up to a lift of 12.3 feet, the ordinary limit being 9.84 feet. For screws he states that if the external water-level descends more than about 1 foot 6 inches below the maximum there will be a wasteful lifting effect. Limits of lift and discharge are 14 feet and 3,500 cubic feet per minute. For suction pumps he gives 2,120 cubic feet and 16 feet 6 inches; for double-acting lift and force pumps in pairs a discharge of 5,300 cubic feet per pair, and 40 feet or more lift. He estimates the maximum discharge of centrifugals at 3,500 cubic feet, and lift 40 feet.

Mr. Korevaar gives the following as the ratios between useful effect and indicated power in the cylinders:—

Float-wheels	0.67
Lift and force-pumps	0.70
Centrifugal pumps	0.45

He also describes investigations carried on at fourteen pumping stations from September 1880 to May 1882 into the consumption of coal by the different classes of machines, the results of which he gives thus in hectoliters of coal consumed per hectare and per meter of lift:—

	Hectoliter.
Float-wheels	1.06
Lift and force pumps	1.06
Similar pumps combined with float-wheels	1.04
Centrifugal pumps	1.77

Whence he concludes that centrifugals consume at least 50 per cent. more coal than the other machines.

The author does not agree with Mr. Korevaar, whose condemnation of centrifugals he considers to be based upon somewhat unfair treatment, those experimented upon being of old-fashioned types, and working under unfavorable conditions. He also, however, considers that centrifugals consume more coal than any other class of pumping machine, and that suction-pumps consume less. He insists again, however, on the necessity of a careful examination of all the features of each particular case previous to deciding what machine to adopt.

THE CONSTRUCTION OF CHIMNEYS.*

By JOHN P. SEDDON.

From "The Architect."

Chimneys, at present at any rate, are integral and important features of ordinary buildings in England. It may be that they can and will ultimately be altogether dispensed with, and our towns made, by the progress of economic science, to resemble those in the East—mere collections of flat-roofed boxes; and these may possibly be fed with fresh air of varied temperature, and drained of their fouled air by some parish pump and common heating apparatus. When this scientific millennium arrives, such dwellings may be left to purely scientific men, to whom æsthetic considerations are questions of superfluity.

I have, however, now to speak as an architect, addressing a sanitary conference, upon chimneys as existent, and I wish to show how they can and should be treated, that they may be practically useful and ornamental as well. They have been both in former times; witness the graceful chimney-shafts of Grosmont Castle, Southwell Priory, Hampton Court, and a host of Elizabethan mansions, the acknowledged picturesqueness of which is mainly due to the treatment of their chimney-stacks. Alas! however, they are seldom either useful or ornamental now-a-days, as a glance at the skylines of our streets will reveal, since they are almost invariably disfigured by ugly cowls and "tallboys." These are but records of domestic misery and discomfort, every one representing a martyrdom, endured until it became intolerable; and their aggregate cost amounts to a tax upon the inhabitants of our cities which, were it an enforced one, might lead to a revolution. Yet the makers of such monstrosities occupy no inconsiderable space in this very Health Exhibition, and recommend their wares as palliatives for a disease which they assume to be not only universal but inevitable. I maintain that it is not the latter, and need not be the former, and that such costly and ugly excrescences may be altogether dispensed with, if but a little attention be given to the proper construction of these portions of our buildings—chimneys and fireplaces.

Now, let me ask, why do our chimneys smoke? Firstly, because, as a rule, air is not laid on or provided to houses as water is; but rather, indeed, it is in general sedulously excluded. The more sanitarily impervious (that is to say, air-tight) we make our dwellings, the more necessary it is to provide for the admission of fresh air to their interiors, and, unless this be done, smoke cannot ascend the flues of their chimneys; secondly, chimneys smoke because the fireplaces are ill-constructed, and gathered over from the openings of the fireplaces to the flues in such a gradual manner as to leave large vacant spaces above the grates, which act as reservoirs for stagnant cold air, by contact with which the smoke is chilled and prevented from rising and being drawn at once into the flues; thirdly chimneys smoke because flues are ordinarily made too large (the usual size is 14 inches by 9 inches); they should rarely be made more than 9 inches by 9 inches; fourthly, because no provision is made in the flues for such down draughts of air as may invade them to expend and exhaust themselves before they reach the fire-place; and fifthly, because the tops of the chimney-shafts are not carefully constructed with guards against wind in a proper and sightly—that is to say, an architectural manner. Usually all such provision is left to be supplemented by some miserable metal makeshifts, by the chimney-quacks whose fantastic creations Dickens satirized so keenly, and yet, as it would appear even from this exhibition, quite vainly.

As it is useless to expect that chimneys can properly perform their office, of conducting readily into the outer atmosphere the smoke from fireplaces, unless their construction is proper throughout, I shall treat of the fireplace, flue and chimney-top as a whole, of which the several parts are inseparably connected; and I shall begin at the bottom with the fireplace, as the most important of the

* A paper read at the Conference of Architects at the International Health Exhibition.

three, and the one most commonly in fault in the case of smoking chimneys, although it is generally the last to be noticed or examined with a view to its correction. The grate itself, however, I shall leave for later consideration, though it is by no means of the least importance.

The first thing to be done is to provide a good and sufficient supply of fresh air to the fireplace from the outside of the building. To insure its being good it is well, when possible, to bring this from as high a level as can be arranged, yet not from the top of the chimney-stack, lest smoke from other flues be drawn down thence with the fresh air. It may be drawn from the lower part of the stack, just above the roof, by special air flues brought down the chimney jambs. This, however, is not always possible, and then it must be brought in through the walls or by pipes through the floors. An advantage of bringing the fresh air to the fireplace, rather than to any other part of an apartment, is that even if cold, it does not produce the inconvenient draughts usually complained of. It spreads thence upwards and gradually, before being finally drawn up the chimney by the fire in the fireplace; whereas, if admitted elsewhere, its passage is direct to the fire, and unpleasantly so to those who may intercept its course. When no provision for air is made, it has to force its way in at windows and doors, with the same result, made all the worse because of the low temperature at which it enters. The air, however, brought to this point, may be tempered or warmed by being made to pass around the grate before it is admitted to the apartment, and an essential for both comfort and health is that it should be so tempered; every grate, stove, or heating apparatus should, in fact, be thus made the fountain or source whence fresh air is admitted to apartments.

The next point to be considered is that of the outlet of the smoke from the fireplace to the flue. The flue should be here contracted at once to its normal size, or rather made a little smaller, immediately above the fireplace, in order to promote a quick draft of the smoke into it. The usual construction of this part of chimneys, already adverted to, does not conduce to this end. The opening of the fireplace is gathered gradually, in an arched form, to the flue, leaving an objectionable space for cold air. Now, arch and chimney-bar may be economically dispensed with by forming a mantle block in Portland cement concrete *in situ*, extending the full width of the wall, and 9 inches longer than the opening, and 9 or 12 inches deep, pierced with the smoke flue in the center, and one for warmed air on either side. These may be circular, and about 8 inches in diameter, and thus being slightly smaller than the flue over, will insure a quick draft to the smoke flue. The side holes are intended as outlets for the fresh air that has passed round the grates, and thus can be conducted by flues built above the mantle block to gratings for admitting it into the apartment, either in connection with the chimneypiece, or just below the ceiling.

The construction of the smoke flue from above the central hole in the mantle block is the next point deserving and requiring consideration, As has been said, this is ordinarily made 14 inches by 9 inches, but this is too large, and as such becomes a frequent cause for smoking chimneys. Flues should not generally be made more than 9 inches by 9 inches in brickwork, and are better if lined with fireclay pipes within such, which reduces them to about 8 inches in clear circular diameter. The interior surfaces of the pipes should not be smooth, or else much inconvenience will be caused by frequent small falls of soot, from its being unable to cling to the pipes at all.

Midway between the top of the mantle block and the ceiling line of the apartment, the smoke-flue should have a portion expanded and formed in such a manner as to break the direct line of ascent of the smoke. This is in order to allow down draughts or gusts of air that have invaded the flues from the top to expend themselves, without checking the smoke as it rises from the fireplace. A flat ledge should be provided in this expanded part of the flue, immediately under the smoke-flue above, that air driven down may impinge upon it, and be diverted, and a sideways rotary motion given to it, directing it upwards again, together with the smoke rising from below. Specially-formed pipes can

be introduced into flues lined with fire-clay pipes for this purpose, and more than one of these may be inserted in the course of the flues with advantage.

We now have arrived at the chimney-stack above the roofs, and the principal object in its construction is to maintain throughout its warmth, as it is there of course exposed to cold and damp; and it is well known and observed that those chimneys which are in external walls are, from this cause, far more liable than others to smoke. Pervious brickwork becomes saturated by rain, and the flues consequently reduced in temperature are unable to maintain the requisite upward draught. It is well, therefore, for this reason as well as for additional strength, that the chimney-stacks above the roof should be built in cement instead of common mortar, and of impervious bricks or stone and lined with fireclay pipes.

The tops of the chimney-stacks need careful arrangement, because the exit of the smoke from them is very liable to be disturbed and hindered by gusts of wind, particularly when beneath other high objects in the neighborhood. There should, therefore, be at the top of every flue an expanded space, within which most down draughts of air will rotate and expend their force without invading the flue below; and there should be louvred openings so arranged as to direct the wind upwards, and so make it to assist, instead of interfering with or retarding, the exit of smoke. This is the object generally and often rightly attempted by the supplementary cowls, at any rate by the best of them, but it may and should be rather executed in proper architectural form, and durable and sightly materials, such as stone, brickwork or terra-cotta, instead of metal. Terra-cotta is perhaps specially suitable, as being very easily manipulated into the somewhat complicated forms required for the purpose.

So much, then, for the construction of these three parts of a chimney, the fireplace, the flue, and the chimney terminal of the stack. Unless all are well and properly executed, no special appliances for particular parts can be of much avail. I have endeavored to point out the general principles that I think should be attended to in connection with them, and believing that the health and comfort of the community is at present very injuriously affected by their general neglect, I earnestly commend them to the consideration of this Conference.

There is, however, one more part connected with the chimney, which is perhaps quite as important as any of the rest with which I have dealt, but what I have to say about it is somewhat more tentative and experimental. This is the grate within the fireplace. Volumes have been written about it, and yet it remains open for discussion and inviting improvement. My contribution to its literature will be short, and yet it will embody the result of much time and thought expended upon it.

Burning coal principally, as we do in England, we have to seek in the consumption of its smoke, or at least of as large a proportion of it as possible, within the grate itself, the solution of the main difficulties we are considering. For the smoke being consumed, smoky chimneys will be cured. The office of the flue will then be to convey away the gaseous products of combustion only, and not soot. This is, I believe, attainable by means of diverting the current of the smoke, after it has issued from the top of the fire, in such a manner as to force it to pass through the body of the fire before it ultimately is allowed to escape up the chimney flue. Perfect combustion is, I think, more to be sought than what is called "slow combustion," and it is a mistake in my opinion to smother a fire in its own ashes, by preventing their dripping through a grating into an ashpan. The cheerful aspect of an English open fire is not likely to be driven out of fashion by even Health Exhibitions; nor if it could be, and the attempt were made, do I think that the public salubrity would be improved by the substitution of any description of close stoves in apartments, notwithstanding the preference they have obtained on the Continent, and to a great extent in America. Nor do I believe that any of the systems that have been proposed for keeping up throughout dwellings an equable temperature, are likely long to curtail the liberty of English subjects to make their several rooms of whatever degree of heat it may please their occupants. I should certainly, therefore, not advise the most ardent believer in such a system to expend capital in build-

ing houses otherwise than at present, or to try to dispense with chimneys, the construction of which I have been dealing with.

But there are many grates shown in this exhibition which presume fresh air to be brought to them, and in which means are provided for warming and distributing such air into apartments, and I cannot too highly commend the system, and advise its universal adoption by the public; and I may point out that this can and should be done, more often than it is, in the case of the kitchen chimney, which is almost always in use, and that the air warmed thereby not being wanted in the kitchen, should be conducted to the general hall of the house, which supplies air to the rooms whenever their doors are opened, though of course there should be means of shutting it off in summer, when it might prove rather a nuisance than otherwise.

Trusting then that soon, if it be not already achieved by any of the grates shown in this exhibition, that most desirable end, the consumption of smoke within the grate itself will be successfully carried out, I conclude these few observations upon the construction of chimneys, waiting discussion thereon from the members of this Conference.

VENTILATION IN CONNECTION WITH WARMTH AND LIGHTING.*

By Captain DOUGLAS GALTON, C.B., LL.D., F.R.S.A.

From "The Building News."

In this lecture I propose to endeavor to explain what are the principles which should guide us in warming our houses, and then to endeavor to show how those principles can be usefully employed in practice. We must all agree that our present arrangements are inconvenient in certain respects, so far as our towns are concerned. When we bring a large number of houses together, as we do in our great cities, the methods which we adopt for warming our houses conduce to the production of a very large amount of smoke and pollution of the atmosphere. The amount of coal which we burn is out of all proportion to the heat which we produce. Therefore, in our towns, the methods to which we resort for warming our rooms load with impurities the air which we have to breathe. Those who have been born and have lived in the heart of London, do not know what the feeling is of breathing fresh invigorating country air. The question is: How can we alter this? The first step toward alteration is to know what conditions we want to obtain. We will consider, in the first place, what advantages our present methods of warming secure for us; and next, how we can secure these in ways less hurtful to our atmosphere. The open fire is the most favorite method of warming. So far as the production of heat is concerned, it is also the most wasteful. One pound of coal is more than sufficient, if all the heat of combustion is utilized, to raise the temperature of a room 20 ft. square and 12 ft. high, to 10° above the temperature of the outer air. If the room were not ventilated at all, and the walls were composed of non-conducting materials, the consumption of fuel to maintain this temperature would be very small; but we must change the air of the room if we are to live in it, or else the act of breathing would render the air so impure that we should die. The air which passes out of the room to make way for fresh air is warm, and carries some heat with it; the fresh air which comes in, if cold, absorbs heat, which brings up its temperature to that of the room. All this entails a development of additional heat. For instance, if the volume of air contained in the room above mentioned were changed every hour, one pound of coal additional would be required per hour to heat the inflowing air, so that to maintain the temperature at 10° above that of the outer air during 12 hours would require 12 lbs. of coal. Besides this, there is a continual

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escape of heat going on through the walls, windows, ceiling, etc., and thus the mere circumstances of occupation of a room entail a greater consumption of fuel than the mere 1 lb. of coal in order to maintain the temperature. But the open fire consumes much more than would be necessary to keep up the heat. The principle of the ordinary open fire-place is that the coal shall be placed in a grate, to which air is admitted from the bottom and sides to aid in the combustion of the coal; and an ordinary fire-place, for a room of 20 ft. square and 12 ft. high, will contain from about 15 lbs. to 20 lbs. at a time, and, if the fire be kept up for 12 hours, probably the consumption will be about 100 lbs., or the consumption may be assumed at about 8 lbs. of coal an hour. But the consumption of fuel enables the open fire to perform other functions besides those of warming. It is a great engine of ventilation. One pound of coal may be assumed to require, for its perfect combustion, 160 cubic feet of atmospheric air; 8 lbs. would require 1,280 cubic feet; but at a very low computation of the velocity of the gases in an ordinary chimney-flue the air would pass up the chimney at a rate of from 4 ft. to 6 ft. per second, or from 14,000 to 20,000 cubic feet per hour; with the chimneys in ordinary use, a velocity of from 10 ft. to 15 feet per second often prevails, giving an outflow of air of from 35,000 to 40,000 cubic feet per hour. We have, therefore, to consider the open fire in two aspects:—1. As a method of warming. 2. As an engine of ventilation. In its aspect of warming, the radiant heat from the fire does not warm the air of the room; the rays from the fire warm the sides and back and parts adjacent to the grate, they warm the walls, floor, ceiling, and the furniture of the room, and these impart heat to the air. The form and material of the fire-place can thus assist materially the warming of the air. The rays should impinge more freely on the walls and floor than on the ceiling. A projecting chimney-piece with a surface favorable to the absorption and emission of heat would be more favorable to the warming and circulation of the air than one which would allow the rays to pass to the ceiling. In an ordinary fire-place the sides should be splayed, as in the Rumford form of grate; the sides and back should be of non-conducting material, with a surface favorable to the rapid absorption and emission of heat. Thus brick or tiles are better than iron for this purpose. Similarly, the degree to which the materials of the walls or floor of the room are unfavorable to conduction, but favorable to the absorption and emission of heat, will have a bearing on the capacity of the room for warmth. The open fire, moreover, has this advantage: that a person can obtain just as much or as little heat as he desires by placing himself in front of the fire or at the side. There is, however, this inconvenience about the open fire. The large volume of air drawn out of a room by the chimney must be supplied from somewhere, and consequently the very means adopted to heat the room tends to produce draughts, because the stronger the direct radiation, or rather the brighter the flame, in open fire-places, the stronger must be the draught of the fire and the abstraction of heat. Let us next consider what are the conditions which we require for comfort. The normal temperature of the human body is 98° Fahr. If it rises much above or falls much below that, death will ensue. But the human body is a furnace in which the process of combustion is continually going on. Therefore, in order to preserve the normal temperature, the body must continually give off a certain amount of heat. By the laws of radiation, a heated body parts with its heat more or less rapidly in proportion to the low or high temperature of bodies near it. Thus, if a hot body be placed near a cold body, the hot body will radiate heat rapidly. If the hot body be near a body less hot than itself, but still hot, it will part with its temperature slowly. Let us apply this to a room. If you are sitting in a room near a cold brick wall, you feel what you think is a draught. It is not necessarily a draught at all. But the side of your warm body turned next the wall parts with its heat rapidly, and you experience a local chill. If you hang a piece of carpet against the wall, the draught is no longer felt, because the carpet checks the rapidity of the radiation. Now, the chief source of heat in the open fire is its radiant heat, and as it warms the walls of the room and the furniture, it takes off any sensation of chill from the walls, &c., although the air may be comparatively

cool. You must next bear in mind that the proportion of radiant heat to the total heat given out by a heated body, depends on the temperature of the body. Thus, with a red-hot piece of iron, or a flame, the great part of the heat given out is radiant heat; whereas, with a body heated to from 150° to 200°, like a hot-water pipe, a comparatively small proportion is radiant heat. Therefore, when you heat a room by means of hot-water pipes, or by means of warmed air, the walls do not get warmed in the same proportion, and although the air may feel warm, the walls may remain cold, so that the heat of the body may be radiated to the walls and give the sensation of chill. I confess that personally I think there is nothing to compare with what my friend, Sir F. Bramwell, calls the pleasant, pokeable fire. But I do feel most strongly that, however much private feelings may incline us all to use the open fire, it is our duty, now that our towns are becoming so vast, to adopt some method of heating which will produce less smoke. It is not as if there was any probable and early limit to the size of London or of other large towns. They grow continuously, and London has progressed at the same steady rate since the beginning of this century. In 1851 it contained a little over 2,000,000 inhabitants, and was looked upon as vast and abnormal. It now contains 4,000,000, and is steadily increasing. The smoke destroys our light, it injures our air, it ruins our furniture, our pictures, our decorations, and with the increase of London, this must go on in an accelerating ratio. But it requires education in the people to get rid of it. The Smoke Abatement Society sounded the first note against this gigantic evil. In response to the demand then made, many new forms of fire-place were proposed; but the practical conclusion to be derived from that exhibition, was that so long as we burn our fuel in the raw state in our rooms and in our kitchens, we cannot get rid of smoke. The main object of the present exhibition is to educate the people in the science of health. The public has long felt the want of pure water, and has obtained a supply of comparatively pure water in the metropolis. The public has not yet become fully alive to the necessity of pure air. It is our business at this exhibition to endeavor to awaken the public mind to this want. So far as purity of air depends on removal of refuse from our midst, there is hope that in that respect this object may be attained, although no doubt even this simple question is much neglected. Dust is generally removed in open baskets, and emptied into open carts, in a manner which seems to have been designed for the purpose of scattering it as much as possible into the surrounding atmosphere. But the purity of air which depends upon the absence of smoke is another matter, and I fear that it will be many years before the selfishness of the community will give way on this point. The first point to consider is, if we dispense with the use of the open fire, how can we obtain that comfort which the open fire-place gives. The comfort of the open fire is due to the warmth it imparts to the floor, the walls, and the furniture. The air of the room is warmed, not by the rays from the fire, but by the warmth imparted by those rays to those various objects. Therefore the air of the room is somewhat cooler than the walls. Now there is undoubtedly greater exhilaration produced by breathing cool air than by breathing warm air. This is readily accounted for. One cubic foot of cold air contains more oxygen, because it is condensed, than the same volume of expanded warmer air. It is thus desirable that air admitted to a room should not exceed from 55° to 60° temperature, for comfort in breathing. This will at once explain to you why the employment of warmed air alone to warm your houses does not give comfort. If the warmed air is admitted at a comfortable temperature for breathing—viz., about 55°, the walls, which derive their heat from the air, will be somewhat below that temperature. The discomfort is caused by the warm body radiating its heat too rapidly to the colder walls. Therefore, if you are to abandon the open fire, but retain its comfort, you must warm the walls and floors, &c., of your rooms. If you can maintain your walls, floors, and ceilings, at a temperature of from 55° to 65°, combined with an adequate change of air, you will not experience much inconvenience from the loss of the open fire, however much you may regret its companionship and its pokeableness, There are four ways in which

we may effect this. In three of these ways one fire in each house in a central position would be used. In the fourth the heat would be applied in the room itself by means of gas. It is probable, however, that a combined arrangement would be desirable. In all the cases where the heat is furnished from one fire, this fire would be in a close furnace for warming each house, or self-contained block of buildings; and thus the fire could be so arranged by means of self-feeding apparatus as to be practically smokeless. The heat from the fire would be conveyed to the various parts of the building by hot air, hot water, or steam. Where warmed air is used, it would be necessary to adapt the house in its original construction to the purpose, because the air would have to flow up, through spaces in the walls, from the basement. Moreover, it would not be economical to bring up the air in the outside walls, because then nearly half the heat would pass direct to the outer air. The warmed air passing up the central walls of the house would part with some of its heat to the walls, and would thus enter the room at a lower temperature than that of the walls. In order to draw up the warm air into the rooms, it would be necessary to have some means of extracting the air from the room, so as to draw in the warmed air. It would not always flow in of itself in this country. Thus you see that the warming by means of fresh air involves ventilation, and moreover requires, if it is to be thoroughly efficient, that your architect should have thought out the whole problem when he first plans the house, and before you build it; otherwise you are met with difficulties at every turn. In the method of heating by hot air alone you have this further consideration: The air in the heating chamber is necessarily at a given temperature, and your house is thus heated uniformly; but it may happen, in this climate especially, that you may want one room to be warm whilst another is cool. It is generally on this account that other methods of heating have been preferred. It is to these methods of heating that I would now direct your attention. These methods are hot-water pipes, or steam pipes, led from the fire, which is placed in some central position and arranged to accumulate the heat in those rooms or other places which it is desired to heat. I will at once say that the arrangements hitherto made for warming by either hot-water pipes or steam pipes have not fulfilled the conditions I have mentioned as being necessary to supply the comfort of the open fire. The method adopted is to accumulate a certain amount of heating-surface in a coil or nest of pipes, or in what is termed, in the United States, a radiator; but the plan of distributing the heat by means of a large flat surface placed close to the wall has been generally adopted. I do not wish to imply that it has not been thought of, because some few years ago, in an Exhibition of Sanitary Appliances, held at the Society of Arts, Mr. Pritchett, of Bishops Stortford, suggested something of the sort. The apparatus consists of a series of receptacles, or cases, for water. The cases themselves were formed of ordinary plates of corrugated metal, strongly put together, but having a small interval between them so as to unroll the water, as it were, into a film, and form a succession of reservoirs of water, about 30 in. in height, more or less, as is required, but only from $\frac{1}{3}$ in. to 1 in. in thickness, enabling them, therefore, to be placed continuously as a dado, or as a series of panels, round any room or building intended to be warmed, and occupying scarcely any appreciable portion of the space of the room or building. The corrugated form given to these reservoirs not only increases the area of the external surfaces, back and front, and imparts strength to the vessels, but secures a certain amount of friction in the action of the warmed water within the vessels, which predisposes it to part with its heat during its circulation. I have never seen this applied in practice on a large scale. These panels might conveniently form the dado of a room, and, if six feet high, would insure the comfort of the occupants of the room, as they would effectually prevent persons in the room from radiating the heat from their persons to the surrounding walls. Such panels all around the room would especially lend themselves to warming fresh air to be admitted into the room. Mr. Pritchett proposed that these should be warmed by the circulation of hot water; but it is certain that it would be more advantageous to employ steam to heat them if they

were established on a large scale. In England, steam is not much employed for heating. We are prejudiced against it. We fear accidents. It is, however, a method of conveying heat which is eminently suited to use on a large scale; and if we are to hope to abolish our smoke nuisance, it is by methods of heating on a large scale only that we may succeed. Steam heating is extremely simple in its application. Steam is easily led to great distances. Steam heated pipes are hotter than hot-water pipes, therefore their effect in warming the air in contact with them is also greater; and, therefore, when heating is required on a large scale, it will be found that it is more economical to use steam pipes than hot-water pipes; besides which, the pipes may be smaller, and thus in both ways expense is saved. Highly-heated steam pipes, moreover, radiate a large portion of their heat to the walls and furniture of a room. Heating by steam is universal in the United States, and the usual system may be described as follows: The steam is conveyed from the basement along pipes to the room or passage where it is wanted to be used, and there it is passed into a cluster or coil of pipes, called a radiator, which gives an enlarged heating surface. The cause producing the circulation throughout the pipes of the warming apparatus is solely the difference of pressure which results from the more or less rapid condensation of the steam in contact with the radiating surfaces; a partial vacuum of greater or less amount is thereby formed within the radiating portions of the apparatus, and the column of steam, or of water, equivalent to this diminution of pressure constitutes the effective head producing the flow of steam from the boiler, while the return current of condensed water is determined by the downward inclination of the pipes for the return course. Therefore, the flow pipe should be carried in as direct a line as possible from the boiler to the highest point; all the coils for heating should be placed on the return pipe, which should be laid in a uniformly descending line back to the boiler, so arranged as to prevent the lodgment of any condensed water on its way there, because, if condensed water lodges in the pipes, most unpleasant and startling noises result. It is a source of economy in steam heating that the condensed water should flow back to the boiler. This is what is called closed circulation, with separate supply and return mains, both of which extend to the furthest distance to which the heat has to be distributed. It is, however, possible to carry the steam and bring back the condensed water by means of a single main, which answers at once for both the supply and the return, either with or without a longitudinal partition inside it for separating the outward current of steam supply from the return current of condensed water. If more convenient, the return of the condensed water to the boilers may be dispensed with, and the steam may be applied in what is called the system of *open circulation*, where a supply main conveys the steam to the radiating surfaces, whence a return main conducts the condensed water either into an open tank for feeding the boiler, or into a drain to run to waste, or for use as hot water, the boiler being then fed from some other source; in either case suitable traps have to be provided on the return main for preserving the steam pressure within the supply main and radiators. The difficulty of steam heating lies in regulating the temperature of the pipes. With hot water you can have your pipes heated to anything you like from 50° to 180°, but with steam pipes it is different. The heat is got up very rapidly when the steam is turned on, and goes off very rapidly when turned off. There are various arrangements for regulating steam heating when applied to warm inflowing air. In the New York Hospital the incoming air is warmed by coils of steam pipes, and generally to a considerable temperature; but in order to prevent the warmed air entering the wards at too high a temperature, this hot air is passed into a mixing chamber, to which cold air can be admitted at will, so that the hot air can be mixed with cold air to the extent necessary to moderate its temperature before it is allowed to flow into the wards. There is, however, one great advantage possessed by coils of steam-heated pipes —they give out a larger proportion of radiant heat to the walls than is given by hot-water pipes. You can easily understand how much simpler it would be to warm Mr. Pritchett's dados and wall panelling by steam pipes carried through

them instead of by hot water. The next way in which heat can be applied is by means of gas. A gas jet warms any surface in contact with it. If, therefore, you enclose a gas jet in a metal case, and if you bring air to feed the gas burner from the outer air, and carry away the products of combustion also to the outer air, you can use the heat of the metal case to warm the surrounding air in the room, whilst the fumes of combustion from the gas will be taken outside and do no harm to the air of the room. Gas jets might thus be applied with the greatest ease to warm Mr. Pritchett's dados and wall panels, the gas jets being placed inside the dado, and the products of combustion carried to the outer air. Mr. Boyle has invented a very efficient method of applying gas to warm inflowing air at an ordinary ventilator. It is in use at the Guildhall. The fresh air inlet has placed in it a pipe which is coiled round. A gas burner is placed at the bottom of the pipe, separate from the air of the room; the products of combustion pass up the coiled pipe, and then down and out to the open air, the pipe being warmed by the heat they give out in their passage, and the fresh inflowing air being warmed by the pipe. Of course, in all these arrangements, air must be extracted by flues or fans, or some other method, so as to ensure a due circulation of air. But, however advantageous gas may be in the methods of its application to warming, and I do not hesitate to say that it can be easily applied so as to be hygienically perfect in that respect; moreover, you can apply your heat at the exact point at which you want it, for you can so arrange it as to give out a low degree of heat for warming fresh inflowing air, or to give out heat to warm your dados and prevent your own body losing its natural heat too rapidly by radiation; or you can use it to give out a high degree of heat, and thus to furnish radiant heat to warm you by direct radiation. It has only to be carefully adjusted to produce all these advantages, yet there is this enormous drawback to its use. At the price of 3s. 6d. a 1,000 cubic feet, it would cost to effect these things about four times the price of coal. I believe that if it could be supplied so as not to exceed double the price of coal, it might be economical to use it, because you can use it when and where you desire it. You can turn it off when you leave your room and turn it on again when you return, and in this climate, where our changes of temperature in winter are so rapid, a uniform heat applied everywhere often becomes oppressive. Let us consider for a few minutes what is the meaning of revolutionizing the methods of warming our houses in the way I now propose. We should not load our atmosphere with soot. Each of the fires in a house requires a separate chimney; and as, if the householder were determined to do all in his power to make the atmosphere impure, smoke which is arrested in the chimney flue in the form of soot is periodically pushed up out at the top of the chimney into the air, not only to the detriment of the occupier of the house, but to that of the neighbors—an arrangement which may be witnessed any morning in houses where chimneys are being swept. These inconveniences result from having separate fires in every house, and for each separate object. Let us consider, for a moment, the amount of labor and expense entailed by the mere supply of fuel upon this separate system. Take, as an example, one house of moderate size. The consumption of coal, at a low calculation, will be 24 tons a year, which would require 12 carts to convey it to the houses—or a street such as Eaton Place would require 12.000 carts to supply it with coal. These carts entail the presence of between 2,000 and 3,000 horses, and each horse causes, by the manure it deposits in the streets, an additional pollution of our atmosphere. When the coal is placed in the house, these 24 tons require to be carried up in coal-scuttles, each holding probably a quarter of a hundredweight. That is to say, that there would have to be carried from the cellar to various parts of the house nearly 2,000 coal-scuttles full of coal. The residue would have to be carried down again in the shape of ashes, probably to the extent of 400 coals-cuttles, independently of the proportion of ashes which get scattered from the fireplace about the room, and have to be cleaned up by the housemaid. In addition to this, the dirt engendered by the smoke and soot sent up into the atmosphere renders much additional cleaning necessary, and entails on the inhabitants of

London a vast expenditure on soap, and on repainting and redecorating our rooms. Indeed, the late Miss Garrett, who was celebrated for her skill and taste as a decorator of houses, told me she had no sympathy with the movement for the abatement of smoke, because she looked upon smoke and fog as specially sent by Providence for the benefit of decorators. The labor thus entailed is wasted force. It entails vast unnecessary labor and waste of fuel. Probably if the price of coal had remained high, as it was in 1875-6, we should ere now have begun to warm our houses in a more rational way.

But it is not on the ground of economy that I advocate a change. It is on the ground of purity of air. So long as we pollute the air with soot, not only is the outside air impure, but the air is so loaded with dirt that the careful householder excludes it from his rooms where possible. You would all be ashamed to supply your guests at a party with bad water. If you were equally ashamed, which you ought to be, to supply them with bad air, we should soon take measures to build our houses so as to keep up a continual flow of fresh air throughout our rooms. And then we should be rapidly compelled to take measures also for warming our houses in a way which would not pollute our atmosphere.

DRAINAGE OF LARGE MARSHES.

By C. E. HOLLISTER, of Lainsburg.

Transactions of the Michigan Association of Surveyors and Civil Engineers.

Marshes are not alike in all features, nor in the ease and manner of their drainage. Those lying nearly level with the great lakes would probably have to be diked and pumped out. But land in Michigan is as yet too cheap to warrant resorting to such an expensive process, and we will therefore omit all this class of swamps, and leave them to the engineer of the future.

The northern part of this peninsula was probably once an island, separated from the main land by a broad strait, extending from Saginaw Bay westerly through the region now known as the Saginaw and Grand River Valleys. This portion of Michigan is still low, and the country between the Saginaw and Grand Rivers, in Gratiot County, is perhaps the lowest point in the water-shed dividing the eastern and western slopes of the State. As this region is some 80 or 90 miles from either Lake Huron or Michigan, the water-courses have little slope, actually showing at some portions of their course, at a moderate stage, no fall in the surface of the water for one or several consecutive miles, and at other times having for 10, 15, or 20 miles no more than 10 to 14 inches fall per mile. Their channels are very tortuous, with many a needless mile through marshes and swamps.

Either the river channel must be deepened or the banks leveed and the marshes drained by pumping. Fortunately the former is much the cheaper in first cost, to say nothing of maintenance.

The problem in such cases is not so much what to do or how to do it, as it is to raise the necessary funds for the work. The present owners are not rich; had they been they would have bought upland; they have no idea that the land will be worth anything if drained, and the work requires a large expenditure all along the line, to which they will never agree except in the case of small streams of say 20 feet in width. The larger streams require some other than the common proceedings under the drain law.

It needs no argument nor any unusual experience to set forth the unhealthfulness of this state of repeated overflow and evaporation under the summer sun. But it seems that argument and facts and long continued agitation may be necessary to convince the people of the State that they can afford to deepen these river channels, and that a just consideration for the health and lives of those living near such streams will warrant

the expenditure and demands the assistance of the State in aiding and urging on this work.

In two noteworthy instances, the deepening and straightening of small streams preparatory to draining the large areas of wet land along their courses have been begun and carried nearly to completion in Clinton County, under the drain law, J. N. Smith as County Drain Commissioner planning and directing the work. The South Maple, or south branch of the Maple, has its source in a pond on sec. 16, T. 6 N., R. 1. W.; finds its way without much channel in a southerly direction through wide marshes for about 2 miles, then makes a sweep east and then northerly to the Maple River on section 4 of T. 7 N., R. 1. W. At the point where it turns east it is about 1 mile from the Looking-glass River, which at that point flows west in wide marshes.

Marsh land extends continuously from the creek to the river and drains into both. It is a noteworthy fact that, if the creek is cut to the depth of 5 feet from the surface of the marsh and a branch extended to the Looking-glass River, it will bring water from the channel of the latter river through the creek into Maple River. The creek drains about one-third of the Town of Victor, and about half of Ovid Township. In some places it flows through a narrow bottom or swale only a few rods wide; but most of the way through marshes or elm swamps $\frac{1}{8}$ to $\frac{1}{2}$ mile wide, the main line being about 17 miles long, and having two branches, one about 4, the other about 2 miles long, laid out and dug at the same time.

From the mouth of the creek, for a distance of 5 miles, the bottom as dug is to be 12 feet wide, and is to be deepened gradually as the valley widens until a depth of 5 feet from the surface is attained. At this point the drainage of about a square mile of marsh and the adjacent highlands enters the creek. Above this place the bottom is narrowed to 8 feet. About four miles up the stream is another branch of some miles in length. Here again the width at the bottom is contracted to 4 feet. At a point about 4 miles further up stream another branch comes in, and the width beyond is again reduced to 2 feet on the om. The whole elevation from Maple River to Cedar Lake is about 95 feet.

It was proposed to make the bottom of drain 4 feet below the surface of the water at the stage when the preliminary survey was made, but the square mile of marsh that drains into it lies so flat that it was necessary to increase the depth to 5 feet. The work was put under contract in August, 1882, and most of the work was done by Jan. 1, 1883. The people along the line were amazed at the idea of going so deep, and thought it unnecessary; now they wish the ditch was deeper.

The cost was $13,000, and the number of acres of wet land which is assessed for benefit is about 3,300, making the cost about $4 per acre were it all to come from this land. About $3,000, however, were assessed to the two towns through which it ran, for benefit to health and highway benefits.

The very remarkable fall in this stream comes from its running north and towards the low part of the State mentioned before. The Cedar River empties into the Grand at Lansing, the Looking-glass at Portland, and the Maple at Lyons. All rise near together and flow nearly west. If then we cross a little west of the meridian, we find the Cedar about 25 feet higher than the Looking-glass, and the Maple about 120 feet below the Looking-glass.

We find still another class of marshes, such as the Chandler Marsh—large, flat; no creek flowing through them, but usually a creek leading from or heading in them. Usually the outlet is level for a long distance, so that we have a flat perhaps 4 or 5 miles long, sometimes double that, and we find that a large expense must be incurred in opening an outlet before we can begin to drain the marsh. When the water is drawn out, such marshes will settle from 1 to 2 feet. The Chandler Marsh has settled so that large stones project a foot, where in a natural state, all was water and soft mud, and no one thought of finding a stone within half a mile. The farther down the stream from the marsh, the shallower is the muck, the firmer the ground, and the less it will settle.

In making our calculations, we must, to save expense, go no farther down the stream than necessary; we must lay the

grade as flat as will work well, and go no deeper than necessary. Conditions have operated so powerfully upon parties in charge of such works, in all the cases which have come to my knowledge, as to over-shadow other less obvious but equally important matters, and have spoiled the job, making it necessary to go all over the same work time and again. Yet if we know and state just what is necessary, we often cannot get our plans adopted, because they look too large.

1. We must allow for the settlement of such marshes and the derangement of our grade. Hence we must cut deeper below and go farther down stream than at first seems necessary. *All fail here.*

2. We must go deep enough to allow the marsh to settle and still be able to drain the further edges of the marsh to a depth of 3 feet with a proper grade to the outlet.

3. The outlet must be large enough to carry the water off freely. We must look up the local water-sheds and see how much water we have to provide an outlet for.

The Perrin Marsh, in the town of Greenbush, Clinton County, is a case in point. For some years they raised quite good crops on the marsh, until the neighbors saw that marshes could be made productive, and had ditches dug running back 1 or 2 miles on each side, but especially on the south. As this is south of the low part of the peninsula, the surface slopes rapidly to the north. These side ditches have a great fall, and flood the marsh by bringing the water in too fast for outlet to carry it off. It also was not dug far enough down the stream. South of St. Johns is a similar case which fails for both these reasons, so that the man who was really the pioneer in reclaiming the marsh is completely drowned out and has lost his entire crop for two years on land where, before that time, he had raised most spring crops, hay and onions.

The Chandler Marsh also has no outlet. The main ditch stands full of water, as any of you who cross it on the J. L. & S. R. R. may see. Of course nothing can be done with land when the water stands in the ditches at a level with the surface.

The water which falls on a marsh is not that which makes the greatest trouble in draining them. It is that which flows on from the surrounding and higher lands, and also that which passes through the soil from the uplands, whether it comes in the form of springs or by an almost imperceptible soaking through the soil. If we run a branch on each side of the large marshes, we shall cut off all this water which comes from the sides. Otherwise it will flow over the surface and keep the whole marsh wet. This water may be drawn in by laterals, and, in small marshes, with but narrow water-sheds on the sides, this is the wiser course, but where a wide marsh is surrounded by a wide strip of flat land, we shall succeed better if we run near the edges of the marsh, and drain from each side of each ditch with laterals.

Some will object to this view, and say that the middle of the marsh will settle most, and hence be too low to drain into the side ditches. In fact, however, the middle of a marsh is generally the highest, and can settle most and yet not be too low; but the main reason after all is, there must be a drain along each edge to catch the soakage, or we shall not have it drained; and the cost will be less than to first make a main through the middle, and then laterals and shore drains. If the marsh is wide, the length of the laterals to bring in the shore water, especially if branch drains are needed as often as one in 40 rods, will be greater than the excess of the shore lines over a main in the center.

DISCUSSION.

Mr. J. J. Watkins did not believe that the bottom of a ditch settles; can see no reason for it, and his experience has proved that the top settles and the bottom rises, so that the ditch gets shallower from two causes. Use an 8-rod tape, and give distance in rods and links; commissioners liked it better.

Mr. S. N. Beden was certain Mr. Holland was correct; had tested the bottom many times by reference to a fixed bench mark; in one case when the levels had first been run by another party, and ditch constructed from these levels, he had occasion to run the levels again, and found a perfect agreement with the first levels on hard land, but on the marsh the result showed either an error of the first party, or that the ditch had settled 12 to

14 inches; believed that the bottom of the ditch had settled; put grade stakes down to grade; there can be no mistake, and they remain in the ditch to show the position of the bottom for all time; get them down by driving with a sledge on a turned and graduated hickory stick, with ferule to prevent splitting; no difficulty in getting them down 4 or 5 feet; consider a grade of 1.6 feet per mile as small as should be used; object to less than .06 foot per 100 feet.

Mr. W. B. Sears thought a better plan was to leave the top of each grade stake 3 or 4 feet above the grade line.

Mr. M. W. Bullock would like to know of a small dredge for such work; has had much difficulty with a floating bog; finally conquered it by constructing a flume in sections and sinking each one to place; prefer to drain small marshes by a center ditch.

Mr. B. F. Welles said that underneath the City of Marshall was a layer of sandstone so porous and dry that it would serve as an outlet to marshes if connected. In one case 10 drive wells in an area of 10 acres removed 10 inches of water in two days.

Mr. Hodgman—In some cases drive wells let water up instead of down; it depends entirely on the underlying strata. Many are dissatisfied with drainage because it is only half done; drainage might as well not be commenced as to be only half completed; had seen drains with a large volume of water work well on a level; get all the fall possible; thought that in marshes underlaid with clay the bottom would rise, and in deep muck marshes it would settle.

Mr. W. Appleton thought that the well method of drainage would always work if the well was made deep enough; had tried it with good success himself, and the well worked well for four or five years; he filled the well with small stone, but in time the silt from the marsh washed among them and ruined the well by filling the pores.

Professor J. B. Davis suggested that the well be made large, and that it be made deep enough, so that it should extend some distance into the water taking strata so as to get a side outlet; a settling well or basin should first receive the water and discharge from its upper surface into the drainage well.

Mr. T. W. Petter generally set stakes once in 20 rods, some commissioners prefer a grade table to a profile; must one be made? (The law requires one.)

Mr. C. E. Hollister believes in putting the drains on the edge of the marshes and not through the center; the water that does the injury comes almost invariably from the upland; would have them far enough from the edge of the marsh to allow the velocity of the water from the banks to be checked sufficiently to deposit debris before reaching the ditch. Clinton County has spent about $60,000 on county ditches the past year, but the principal construction has been done by hand. The cost for a ditch with an average depth of 5 feet, bottom width 8 feet, top width 24 feet, has been $5 per rod. The best results were obtained when each man could be induced to take the contract on his own land; had much difficulty with floating bogs. It is impossible to dig them out, when soaked with water; have had good success in freezing weather, by digging but little faster than the muck would freeze; the least grade depends on volume of water; for ordinary ditches should be 1 ft. per mile.

An Aboriginal Dwelling.—A short time ago there was discovered in a marsh at Schussenried, in Wurtemburg, a well-preserved hut of the age of stone. The flooring and a part of the walls were intact, and, as appeared from a careful admeasurement, had formed, when complete, a rectangle, 10 meters long and 7 meters wide. The hut was divided into two compartments, communicating with each other by a foot-bridge made of three girders. The single door, looking towards the south, was a meter wide, and opened into a room 6.50 meters long and 4 meters wide. In one corner lay a heap of stones, which had apparently formed the fireplace. This room was the kitchen, "the living room," and probably a night refuge for the cattle in cold weather. The second room, which had no opening outside, measured 6.50 meters long and five meters wide, and was, no doubt, used as the family bedchamber. The floors of both rooms were formed of round logs and the walls of split logs. This, be it remembered, was a hut of the Stone Age. It may be safely presumed that the lake dwellings of the Bronze Age were larger in size and less primitive in their arrangements. At both periods the platform supporting the houses communicated with the shore by means of a bridge (probably removable at pleasure) and with the water by ladders. These ladders, as appears from an example found at Chavannes, were made of a single stang with holes for the staves, which protruded on either side.—*Contemporary Review.*

LIGHTHOUSE ILLUMINANTS.

From the "English Mechanic."

The great practical advances made of late years in the various systems of illumination led to the appointment of a committee to investigate the most modern appliances, and to report upon their relative merits, with special reference to their adaptability for lighthouse purposes. This committee, it will be remembered, was dissolved last year, for reasons which were publicly stated at the time, without having effected any practical work. The Board of Trade, however, subsequently afforded the Corporation of the Trinity House the opportunity of undertaking the investigation, and eventually intrusted the carrying out of the necessary experiments to the Elder Brethren. Thereupon a committee of the Elder Brethren was formed, which consists of the following members:—Captain Sydney Webb (Deputy Master of the Corporation of the Trinity House), chairman; Captain Nisbet, Captain Weller, Captain Burne, Captain Vyvyan, Admiral Sir Leopold McClintock, and Mr. Inglis, the secretary to the Corporation. Mr. Price Edwards, who was the secretary to the previous committee, acts in a similar capacity with regard to the present one. Sir James Douglas, the engineer to the Corporation, is advising the committee on points of detail, and the photometric observations are intrusted to Mr. Harold Dixon. Mr. Vernon Harcourt, F.R.S., is watching the experiments on behalf of the Board of Trade. The Corporation of the Trinity House is acting in conjunction with the Scotch and Irish Lighthouse Boards, and the representatives of various foreign Governments are taking an active interest in the experiments, which, we need hardly observe, promise in their results to prove of the highest importance to the maritime nations of the whole world.

Immediately upon their appointment the new committee took the necessary initiatory steps towards carrying out an elaborate and exhaustive series of experiments with three available illuminants—oil, gas and electricity. To this end they selected the South Foreland for the scene of operations, as being the most convenient and advantageous for the purpose. There are already two lighthouses there, known as the high and low lights, which are illuminated by electricity. By the forethought of the Trinity House engineer a surplus of engine power was provided at starting, and is available for the present electrical experiments. Then the surrounding country, being comparatively flat, or only slightly undulating, and the view unimpeded by trees or hedges, renders it a most eligible spot for taking observations far and near.

It is worthy of note that the South Foreland lighthouses, which were originally illuminated by means of coal fires, were the first in which electricity—carbon in a more refined and more highly intensified form—was adopted as an illuminant. This was in 1857, when Professor Holmes first submitted his system of lighthouse illumination by electricity to the Trinity House, and received permission to establish his apparatus in the high light, the system being afterwards extended to the low light. England was thus the first to adopt electricity for lighthouse illumination. The machinery and apparatus used for these two lights consist of four of Professor Holmes' magneto-electric machines—two for the high and two for the low light—which are both powerful and safe, producing a low tension current not exceeding 60 volts. They are, moreover, very reliable, costing little or nothing for repair. There are two horizontal steam engines of the single-cylinder type by Messrs. Hunter and English, each of 10 horse power nominal, but capable of developing 30 horse power each. Steam is supplied from a Cornish boiler 15 ft. long by 6 ft. diameter, and of which there are two, one being kept in reserve, as is also one of the engines, a single engine sufficing to drive the four Holmes machines, and those used in the experiments to which we shall presently refer. And here we may mention that upon our recent visit we found a very important permanent addition was being made to the South Foreland establishment. This consists of a

long one-storied brick building which is being erected by the Trinity Board for the purpose of conducting photometric experiments with very powerful lights, for which at present there exist no adequate means. This shed is 380 feet in length, and it will be fitted with the necessary appliances for light testing, and there in future all the large lights will be tested.

In connection with the experiments three temporary wooden towers have been constructed in a line landwards and bearing north-west from the permanent high light. These towers are marked A, B, and C, and are respectively used for the electric, the gas, and the oil light. Tower A is 245 feet from the high light, and tower B 180 feet from A; tower C being the same distance from B. The focal plane of all the towers is 15 feet below that of the electric high light, which is 380 feet above sea level. In the electric arrangements Baron de Meritens' arc lamps and magneto-electric machines are employed. At present there are two of these lamps and two of the machines in place, but another of each is to be added. The lamps are placed one above the other, or superposed, in the tower. The carbons used in them are compound—that is, they are made up of a number of small carbon rods of square section. The carbons in use at the time of our visit were $1\frac{1}{2}$ inches square, and were composed of 49 small square rods, but since then the new Berlin Code carbons of Messrs. Siemens have been employed. The two machines for producing the current are placed in the engine house with the others, and, as we have stated, are driven by the same engine as the Holmes machines. Each of the De Meritens machines is arranged for working at one-fifth, two-fifths, three-fifths, and at full-power, the estimated intensity of the light from each machine at those powers being respectively 6,000, 12,000, 18,000, and 30,000 candles. The machines can either be worked singly or coupled up. Like the Holmes machines, those of De Meritens produce a low tension current, and are found to be very reliable in operation and inexpensive in maintenance. The arrangements for illuminating tower B consist of a small gasworks erected by Mr. J. R. Wigham, of Dublin, whose burners are used in the tower, his system having been adopted for lighthouses on the Irish coast. The gasworks were put up and the gas illumination is now being carried out under Mr. Wigham's supervision. The gas-producing apparatus consists of a small retort house fitted with two benches of three retorts, the necessary purifiers, and a holder capable of containing 4,500 cubic feet of gas. The gas is passed through a meter placed outside the tower to the burners within it, and which are four in number. Each burner is composed of a series of concentric rings of jets, and the light can be started with a minimum power of 28 jets, and increased by gradations of 20 jets up to 108 jets, the full power of each burner, at which it develops 3,000 candle power. There are four of these burners superposed, and they can be used either singly or together, the lights being designated uniform, biform, triform, and quadriform, according to the number of burners in use at the same time. The object of the variations of power in the lights in all cases is to meet the varying requirements of the atmosphere.

In tower C, oil lights are used, and these are produced by means of burners of the recognized Trinity House pattern. For this purpose nothing further is necessary than a tank outside the tower containing a store of Scotch paraffine and the lamps and burners in the tower. The oil is supplied to the burner from the lamp under slight pressure by means of an arrangement similar to that adopted in obtaining hydraulic power, oil, of course, taking the place of water. The burners at present in use have six concentric wicks, each burner developing 720 candle power; but Sir James Douglas is preparing another burner of much higher power, having seven wicks, which will shortly be tried. The burners are arranged in three stages, and either a uniform, a biform, or a triform light can be exhibited as required. The burners are in duplicate on each stage, and by an ingenious arrangement the first lamp can be shunted out of position if necessary, and the second one lighted and shunted into its place without any appreciable loss of time. Sir James Douglas has also devised a very simple but effective arrangement for ventilating lighthouses by means of which the heated air is carried rapidly off, but the atmosphere of the

lighthouse is kept perfectly steady to a very high elevation in the coned roof, as was shown by experiments in this tower.

Such are the arrangements for producing the various lights. For testing them, carefully elaborated arrangements have been made. An overland route has been laid down as a line of observation for a distance of $2\frac{1}{2}$ miles from the towers in the direction of Deal, and stakes have been driven at every 100 ft. At half a mile from the towers on this route is hut No. 1 for taking photometric observations, and this is more particularly intended for fog work. At $1\frac{1}{4}$ mile we come upon hut No. 2, which is likewise fitted with photometric apparatus. At the limit of the range is the third hut, each hut being conveniently fitted up for the residence of the official in charge. Arrangements have also been made for observations to be taken at the various coastguard stations within the focal area, at Ramsgate and other contiguous places, and at various points out at sea, including the Gull and Varne light vessels, which are respectively 8 miles N.E., and 12 miles S. W. distant from South Foreland. The observers are supplied with books for recording their observations in tabular form, which will ultimately be collected and their contents collated for the information of the committee. The books contain directions as to the method of procedure in making observations. Observers are also provided with charts for land and sea observations, showing the illuminated areas to the north and south of South Foreland. The committee have quarters at St. Margaret's, contiguous to the experimental towers, where one of their body will always be in residence. Ranging over so wide an area as they will, and involving so many investigations as they do, we need hardly say that the experiments will occupy several months, probably five or six. Every illuminant and variety of burner adapted for lighthouse illumination will be tested under every possible condition pertaining to itself and to the atmosphere. The most important point as regards atmospheric conditions will be fogs, which will have very careful consideration. Upon the occasion of our recent visit splendid lights of varying intensities were produced at night by each of the three systems under trial. The preliminary photometric observations appear to indicate that the electric light in comparison with either the gas or the oil light is as the sun is to a candle. This, however, is but natural, but, as a result, it has to be considered in connection with a variety of other conditions into which it is not only unnecessary, but inexpedient for us to enter. The experiments have at first been confined to the testing of apparatus and contrivances already in use. A further stage will be devoted to any other burners and appliances which shall be submitted to the committee, and after inspection by them shall be adjudged suitable for lighthouse illumination. It is thus open to the whole world to assist in promoting a movement of the first importance, which in its results cannot fail to prove of the highest value to every maritime nation.

THE SOFTENING OF WATER.*

BY BALDWIN LATHAM, M. Inst. C.E., F.G.S.

From "The Building News."

FROM the remotest period of antiquity, the art of softening water for the purposes of washing and cleansing appears to have been known and adopted. Soap is very largely used, or rather wasted, in many places in the present day for softening water, for which it is now well understood that no useful effect in washing is produced until sufficient soap has been used as to soften the water. For the purposes of this investigation water may be divided into two classes, hard and soft. Hard water is a water which contains salts of lime, magnesia or iron, and sometimes an amount of free carbonic acid. A hard water is one that destroys soap in washing, while a soft water is one that does not destroy soap. A soft water

* A paper read at the Society of Arts Water Supply Conference, July 25, 1884.

may derive its properties from an absence of earthy salts, or it may have become soft by reason of the presence of certain alkaline salts in the water, notably the salts of soda and potash. Hard waters may be divided into two classes, those which are permanently hard and those which are temporarily hard. Generally a single sample of naturally hard water partakes of both these properties. A water which is said to be temporarily hard becomes soft by boiling, as the hardness is due to salts of magnesia or lime dissolved in the water by the agency of carbonic acid, or due to the presence of this gas in a free state in the water. Under either circumstances the effect of boiling the water a sufficiently long time is to drive off the carbonic acid gas, and a natural softening of the water takes place from the absence of this gas, and the earthy salts that have been held in solution by it in the water. Water that is perfectly hard derives this property from the presence of the same salts as are in water temporarily hard, but instead of being combined with carbonic acid they are combined with sulphuric acid, and to soften water that is permanently hard requires very different conditions than is the case with waters that are only temporarily hard. The qualities of a good drinking water have been described as: 1st. Freedom from vegetable and animal matter. 2d. Pure aëration. 3d. Softness. 4th. Freedom from earthy, mineral or other foreign matter. 5th. Coolness and delivery at the minimum temperature. 6th. Lucidity or clearness. 7th. Absence of taste and smell. Although many authorities insist that for the sake of health a soft water is beneficial, on the other hand, there are those who contend that there is no evidence whatever to show that even a hard water has any influence upon health. It is clear, so far as the health statistics of this country are concerned, that, if anything, the results come in favor of persons inhabiting districts having hard waters. On the other hand, it has been thought that particular diseases which affect particular localities, such as cretinism and goitre, are due to certain salts of magnesia which have been found in the waters of the district. Some waters which are of remarkable softness, in which the softness is due to the presence of certain alkaline salts, especially those of soda, may be quite unfit for drinking purposes. A type of this water is found in the well supplying the Trafalgar square fountains, as it is stated that the large amount of soda contained in it, if taken habitually, acts medicinally upon the kidneys. It is also unfit for washing, as the water is liable to destroy certain colors and stains glass. It is said to be unfit for bathing, as the soda combines with the oily matter of the skin, producing a roughness and liability to chapping. Water, however, which is naturally soft, or which has been softened by means of a process like Dr. Clark's, which does not add any new element to the water, has great advantages for many purposes. It prevents incrustation of steam boilers and household utensils, it results in a saving of fuel, less wear and tear in washing linen, and in the labor of cleansing; it saves soap in all washing and cleansing operations, the water cleans better, and gives a better color to linen, and it is also stated to lead to greater economy in tea-making and brewing, but whether this is correct or not is very doubtful, as water used for such purposes is always boiled, and when used in that state should be as soft as softened water. The processes which have been used both in ancient and modern times, may be comprised under the heads of boiling, chemical processes, distilling, exposure, freezing.

SOFTENING BY BOILING.

The effect of boiling water is to liberate the carbonic acid which holds certain alkaline salts in solution, and on the liberation of the acid these salts are precipitated, and form the coating which furs our kettles, accumulates in our boilers, blocks the circulating pipes of our water-heating apparatus, and is often a source of danger, and always of expense. The effect of boiling water in order to soften it can only be secured when this operation is sufficiently prolonged. The commissioners appointed to inquire into the chemical properties of the water of the metropolis in 1851, made some experiments on the effects of boiling an artificially prepared hot water containing 13.5 grains of carbonate of lime per gallon, and it was found to decrease in hardness from 13.5° to 11.2° by being heated to the boiling point; after boiling for 5

minutes it was reduced to 6.3°, for fifteen minutes to 4.4°, for thirty minutes to 2.6°, and for one hour to 2.4°, so that the softening effect does not take place at once, but a prolonged boiling is required in order to produce the greatest degree of softening. In order to get rid of the temporary hardness of water, sharp boiling for not less than twenty minutes is requisite, but boiling water does not remove the hardness occasioned by the salts, which are neutral; in fact, the permanent hardness of the water is increased by boiling, as all the water evaporated leaves a concentration of the neutral salts in the remaining water. It has also been shown that the alkalinity of water is more after boiling than when softening has been produced by an alkaline salt, such as lime; but both have the effect of reducing the hardness to about the same degree. This increase of alkalinity after boiling is attributed to the concentration of the neutral salts consequent on the loss by evaporation. The temporary salts held in solution by water are precipitated by boiling, and it is these precipitated salts which cause the furring of kettles, hot-water boilers, steam boilers, and hot-water pipes, and have led to the adoption in certain cases of means either for retaining the salts in solution in the water, or of preventing their deposit in steam boilers, but as a rule with only partial success.

CHEMICAL PROCESSES OF SOFTENING WATER.

In a paper read before the Literary and Philosophical Society of Manchester, in 1781, by Thomas Henry, F. R. S., a description is given of a mode of preserving sea water by means of quick lime, in which the author pointed out that the earthy base of magnesia was precipitated in sea water by lime, and its place taken by a calcareous salt. He also referred in this paper to the well-known action of quicklime on common water as a preservative. The effect of the lime, doubtless, upon the sea and fresh water was to induce abundant precipitation, which dragged down with it certain organic impurities, and as a consequence the water remained free from putrefactive influence afterwards, as was clearly shown in the course of his experiments. The first patent for purifying water by chemical agency in this country was taken out in 1838, for precipitating by muriate of zinc and salts of soda, the latter salts precipitating the zinc from the water, leaving the water in a purified state. In 1841, Dr. Thomas Clark, of Aberdeen, took out a patent for his well known and beautiful process for softening water, and which has, more or less, been the basis of all other patented processes of this description which have been adopted since that period. Dr. Clark thus described his process in May, 1856:

"In order to explain how the invention operates it will be necessary to glance at the chemical composition and some chemical properties of chalk, for while chalk makes up the great bulk of the matter to be separated, chalk also contains the ingredient that brings about the separation. The invention is a chemical one for expelling chalk by chalk. Chalk, then, consists, for every one pound of sixteen ounces, of lime, nine ounces; carbonic acid, seven ounces. The nine ounces of lime may be obtained apart by burning the chalk, as in a lime kiln. The nine ounces of burnt lime may be dissolved in any quantity of water not less than forty gallons. The solution would be called lime water. During the burning of the chalk to convert it into lime, the seven ounces of carbonic acid are driven off. This acid, when uncombined, is naturally volatile and mild; it is the same substance that forms what has been called soda water when dissolved in water under pressure. Now, so very sparingly soluble in water is chalk by itself that probably upwards of 5,000 gallons would be necessary to dissolve one pound of sixteen ounces; but by combining one pound of chalk in water with seven ounces additional of carbonic acid—that is to say, as much more carbonic acid as the chalk itself contains—the chalk becomes readily soluble in water, and when so dissolved is called bicarbonate of lime. If the quantity of water containing the one pound of chalk with seven ounces additional of carbonic acid were 400 gallons, the solution would be a water of the same hardness, as well water from the chalk strata, and not sensibly different in other respects. Thus it appears that one pound of chalk, scarcely soluble at all in water, may be rendered soluble in it by either of two distinct chemical

changes: soluble by being deprived entirely of its carbonic acid, when it is capable of changing water into lime water, and soluble by combining with a second dose of carbonic acid, making up bicarbonic of lime. Now, if a solution of the nine ounces of burnt lime, forming lime water, and another solution of the one pound of chalk and the seven ounces of carbonic acid, forming bicarbonate of lime be mixed together, they will so act upon each other as to restore the two pounds of chalk, which will, after the mixture, subside, leaving a bright water above. This water will be free from bicarbonate of lime, free from burnt lime, and free from chalk, except a very little, which we keep out of account at present, for the simplicity in this explanation. A small residuum of the chalk always remains not separated by the process. Of $17\frac{1}{2}$ grains, for instance, contained in a gallon of water, only 16 grains would be deposited, and $1\frac{1}{2}$ grains would remain. In other words, water with $17\frac{1}{2}$ degrees of hardness arising from chalk can be reduced to $1\frac{1}{2}$ degrees, but not lower. These explanations will make it easy to comprehend the successive parts of the softening process. Supposing it was a moderate quantity of well water from the chalk strata around the metropolis that we had to soften, say 400 gallons. This quantity, as has already been explained, would contain one pound of chalk, and would fill a vessel 4ft. square by 4ft. deep. We could take 9 ounces of burnt lime made from soft upper chalk; we first slake it into a hydrate by adding a little water. When this is done we would put the slaked lime into a vessel where we intend to soften water gradually. Add some of the water, in order to form lime water. For this purpose at least 40 gallons are necessary, but we may add water gradually until we have added thrice as much as this; afterwards we may add the water more freely, taking care to mix intimately the water and the lime water or lime. Or we might previously form saturated lime water, which is very easy to form, and then make use of this lime water instead of lime, putting in the lime water first and adding the water to be softened. The proportion in this case would be one bulk of lime water to ten bulks of the hard water. It is of importance that the lime or lime water, that is, the softening ingredient, be put into the vessel first, and the hard water gradually added, because there is thus an excarbonate of lime produced in the process more easy. But what you will wish to know now is by what mark is the conductor of the process to find out when there is enough of water to take up the last of the excess of lime, so as to be enough, but no more. This is done by what has been called the silver test, the only test necessary to the operator after the process is fairly set a-going. This test is a solution of nitrate of silver in twice distilled water, in the proportion of an ounce per pint. In making use of the silver test in ordinary water we get a white precipitate; but if the water have in it a notable excess of lime water, there is a light reddish brown precipitate produced; but if the excess be very slight, we only get a very feeble yellow precipitate. The way we make use of the test is to let two or three drops of it fall on the bottom of a white tea cup; then add the water somewhat slowly; then, if there be the slightest excess of lime, a yellow color will show itself."

It may be here mentioned that a more delicate test than the silver test, for ascertaining if there is an excess of lime in the water, consists in using a solution of cochineal, the natural color of which is yellowish red, which is turned violet in the presence of alkalies; and other agents are now used to show, by distinct color or its absence, if there is an excess or not of lime in the softened water. According to Dr. Clark's scale, 1° of hardness means that there is one grain of chalk in a gallon of water. According to the scale introduced by Dr. Frankland, in the sixth report of the Rivers Pollution Commissioners, parts per 100,000 are used, or one grain of chalk in 100,000 grains of water, so that it is necessary, in considering the reports of the Rivers Pollution Commissioners, to bear in mind this difference of degrees of hardness. To reduce the hardness to parts per gallon, or to the Clark scale, it is necessary to multiply by 7 and divide by 10. Hard water decomposes soap. The amount of soap ascertained by Dr. Clark to be wasted before softening the water is equivalent to 2 ounces for each degree of hardness for every 100 gallons. Dr. Clark introduced a soap test, or a means by which a solu-

tion of soap is made to at once indicate the degree of hardness of a water. When pure chalk is burnt into lime, one pound is converted into 9 ounces of lime, and this quantity is soluble in 40 gallons of a water. Beyond this, lime is not soluble in water, so that clear lime water always possesses a known composition. This amount of lime is equivalent to 98.43 grains per gallon. As one particle of lime will remove $\frac{16}{9}=1.77$ of chalk, it follows that $98.43 \times 1.777 = 174.9$, or the number of gallons of water 1° of hardness which one gallon of lime water will soften. In practice, however, while theoretically 175 gallons of water of 1° of hardness may be softened by one gallon of lime water, owing to the impurities in the lime, probably not more than 140 to 150 gallons would be softened, so that, to arrive at the amount of lime water necessary to soften hard water, if we divide 150 by the degrees of hardness according to Clark's scale, it will, generally, roundly represent the number of gallons of water which can be softened by one gallon of lime water. Neither by boiling nor by the lime process can all the hardness which is termed "temporary hardness" be removed; in fact, a small quantity of chalk, to the extent of one part in 5,000 parts, is insoluble in water, and still remains in solution after the process. In practice, however, 10-11ths of the whole of the temporary hardness may be removed by the lime process. In carrying out the Clark process, the lime water is usually applied, owing to the fact that it is a standard liquid containing a known quantity of lime, although cream of lime is sometimes used with advantage. Large tank space is required to carry out the Clark process, three tanks ordinarily being required, one for filling up, another for drawing down, and a third in reserve while cleansing is going on, and each tank should hold a day's supply. It is important to know that the salts of iron may be readily removed by the application of lime. This the author found in the case of a waterworks at Horsham, where the water was so highly charged with iron that everything it touched was discolored; but by the application of lime the whole of the iron was removed. It should also be noted that the process has a marked effect in removing organic matter from water. This was shown by the Rivers Pollution Commissioners, and by the analysis published by Professor Wanklyn, especially in the marked diminution in the amount of albuminoid ammonia. The great objection raised against soft water has been its liability to produce lead poisoning; but the concensus of opinion is that water softened by the Clark process is not liable to attack lead, which is a point of very considerable importance in favor of the process. Dr. Clark's process was first carried out by the Woolwich and Plumstead Waterworks Company, where it was shown that the water was successfully softened from 23° to 7°. These works were subsequently bought by the Kent Waterworks Company, and the process of softening the water was discontinued. In the course of experiments made in softening various waters, it was observed that, if the water was at all tinted, the softening process did not clear it; but there was a tendency for the matters separated to remain in suspension in such water, so that it was considered expedient, in softening river water, that the water should be filtered until quite bright before it undergoes the softening process. In 1852 a patent was applied for (W. B. Bowditch) to treat water with clay and alkali, and subsequently filtering. Mr. Philip H. Holland, M. R. C. S., late inspector to the Burial Acts Office, suggested as an addition to the Clark process the use of oxalate of ammonia or soda to further reduce the hardness of the water after treatment by this process. The use of carbonate of soda for softening water has been known throughout the whole country by tea-makers from an early period. This salt added to water acts on the bicarbonate of lime and magnesia, and precipitates chalk and carbonate of magnesia. It also decomposes the sulphates of lime and magnesia, precipitating the lime and magnesia, while the soda remains in solution, so that the permanent hardness of the water is reduced by the use of this salt. The process, however, of using soda is much more expensive than the ordinary lime process, about $4\frac{3}{4}$ times as much soda being required to produce the same results as in the case of lime. An old recipe for softening water, and useful for some do-

mestic purposes, is as follows: Dissolve 6lbs. of pearlash, or sub-carbonate of soda, in a gallon of soft water, boil the solution, and when boiling add 2ozs. of soap, and stir until all the soap is dissolved. When this solution is added to water to be softened, the carbonate of soda and the soap combining with the salts, producing both temporary and permanent hardness, form an insoluble compound by the combination with the soap, which coagulates and rises to the surface of the water, and may be skimmed off. As any of the earthy alkaline earths may be used instead of or in addition to, lime, it is not surprising that, since the date of Clark's patent, numerous patents have been taken out for softening and purifying water in which lime, in combination with other alkaline earths, have been proposed. For example, in 1849 Mr. John Horsley took out a patent for the use of calcined or caustic barytes, phosphate of soda, oxalic acid, or preparations of these substances. In 1850, lime, in combination with chloride of barium was patented. In 1852, hydrate of potash and hydrate of soda, clay and alkalies were the subjects of separate patents. In 1853 and 1854, hydrate of barytes and hydrate of strontia formed the subject of patents. In 1855 a patent was taken out for a powder containing oxalate of ammonia, peroxide of manganese, and charcoal. In 1856, silicate of soda, in combination with carbonate of soda, was patented. In 1856, bicarbonate of soda and oxalic acid, in crystals, were again proposed to be used. In 1856 and 1857, carbonic acid was proposed to be introduced in conjunction with hydrate of lime. In 1860, bicarbonate of soda and silicate of soda were again twice patented. In 1862 the ordinary lime process was repatented. In 1863 the use of chloride of barium was patented. In 1865, hypermanganate of potash, carbonate of soda, alum and neutralized aluminite, or a solution of iron was proposed; and in another patent, sesqui-sulphate of alumina was proposed as a means of purifying water. In another patent, taken out in 1865, the use of soda and lime is again patented. In 1866 a patent was taken out by a Mr. J. W. Tobin for an improvement on the Clark process for mixing the lime and filtering. In 1866 the use of chlorine and permanganates, in combination with any alkaline earth, was patented. In 1867 a patent was taken out for a preparation in a portable form, consisting of marshmallow, linseed, bran, starch, gum, or any softening ingredient, for the purpose of softening water for ablution purposes. In 1868, the use of barytes was again patented, and the precipitate removed in vessels of a cellular form. In 1869, the use of steam applied to water as a means of softening it was patented, the particles subsiding on shelves arranged in a vertical vessel. In 1872, unslaked lime and sulphate of soda were patented as a means of purifying water. In 1873, the lime process, in conjunction with a mixing and filtering arrangement, was patented; also lime, carbonate of soda, chloride of barium, or other reagent in conjunction with filtering. In 1874, the treating of water with lime and carbonate of soda in combination with filtration was proposed. In 1875, the lime process, pure and simple, and in combination with other reagents and filtering, was patented. In 1876, the lime process in combination with filter presses was first patented by Mr. Porter. In 1877, the use of oxide of magnesia and basic carbonate of magnesia was proposed; also the use of a carbonate of potassa, silicate of soda and niter cake, used separately or combined. In 1878, a patent was taken out for combining bicarbonate of soda with the lime process, and filtering upon the Porter-Clark plan. In 1879, Mr. Porter took out an additional patent for carrying out automatically the softening and purifying of water. In the same year phosphoric acid and phosphate of lime were proposed as a means of softening water. In 1880, the means of automatically carrying out the softening process, and adjusting the qualities by means of an arrangement of ball valves in a cistern, was patented. In 1881, Mr. Porter took out a further patent for the automatic regulation of the supply of the solution of lime. In 1881, Mr. Atkins took out a patent for treating water with lime, and subsequently filtering through a specially-constructed filter. In 1882, an apparatus for softening and clarifying water was proposed, in which sloping shelves in a vertical vessel were used, the water entering the bottom of the vessel and flowing off at the top; or

concentric cylinders overflowing from one to another might also be used with the same object. In 1883, Messrs. Gaillet and Huet's apparatus for softening water was patented, consisting of sloping and V-shaped shelves in a vertical vessel, the water entering at the bottom and flowing out at the top. The use of steam and caustic soda was also patented. A patent was also taken out for the use of phosphate of soda, and an apparatus for measuring the water and lime to be used in the softening process.

MODERN INVENTIONS FOR SOFTENING WATER.

The modern inventions for carrying out the Clark process may be described as the application of machinery to the saving of time, space and labor. Of those in general use, dealing with them in the order of date, the Porter-Clark process comes first. In the ordinary Clark process, lime water, in known quantity, is first admitted into a tank, to which the water to be softened is added. However, in some cases, the lime water and the hard water are allowed to flow in together into the tank, but it was considered by Dr. Clark to be an advantage, in carrying out this process, for the hard water to be brought into contact with an excess of lime water in the first instance, which was led into the tank before the water to be softened was added. In the ordinary Clark process, not less than 16 hours were required for the softening and subsidence of the matters separated from the softened water. In the Porter-Clark process, instead of allowing the particles of carbonate of lime to separate and subside, a brisk agitation is maintained, so that these particles remain in suspension, so as to permit chemical reaction with the lime, and the purification of the hard water which, when completed, is passed onward to filter presses, where the carbonate of lime adheres to the filtering cloth. The subsequent operations of filtering through the deposit on the cloth then takes place, and the water is passed away at once in fit state for use, so that the process is continuous in its action, and may be carried on just as quickly as water may be pumped from a well, provided the apparatus is of sufficient capacity to allow time for the water to remain in contact with the lime in passing through the machine. The lime in this case is passed through horizontal cylinders, which are termed lime churns, and is constantly churned up with water, and the lime water so made is, by suitable arrangements, allowed to mix with the ordinary water in proper proportions, after which it is again agitated. Mr. Porter has also an apparatus by which, instead of using ordinary filter presses, he can use filter frames, and where power is not available, he also suggests a means of working the process without such power. In some cases the power obtained from the pressure of the water is utilized for working the apparatus. An apparatus of this description may be seen at the Camden Town locomotive sheds of the London and North-Western Railway, and the apparatus may also be seen at work within the Health Exhibition.

THE ATKINS PROCESS

Is also a modification of the Clark process, by which the space formerly required is reduced. The lime is put into a vessel where lime water is formed, and this water is allowed to mix in its proper proportion with the water to be softened in a specially-arranged mixing vessel, after which it passes into a reservoir of small dimensions. From this reservoir it is conveyed to filtering vessels which contain a special arrangement of filter, consisting of a series of chambers mounted upon a central hollow shaft, these disc chambers being covered with prepared canvas, upon which the deposit of chalk, &c., adheres, and through which the softened water filters. The filters are cleansed by means of revolving brushes. The apparatus does not require power to maintain it while at work, the only power used being that necessary to give motion to the brushes when the apparatus is cleansed. The system may be seen at work at the Henley-on-Thames Waterworks, and at other places.

IN THE PROCESS OF M. MAIGNEN

A powder is used which the inventor calls "Anti-calcaire." This powder is made of variable composition in order to suit the special characteristics of the water to be treated, the ingredients used for ordinary hard water being lime, soda and alum in suitable proportions. In the apparatus, which is at work at the International Health Exhibition for soft-

ening water for some of the breeding tanks, the water entering the apparatus gives motion to a water-wheel, which in its turn works an arrangement for distributing a given quantity of the softening agent, and causing it to pass into the water. The water is then allowed to subside in a small tank, and is eventually filtered through filters covered with asbestos cloth, the basis of the filter being similar to that of the "Filter Rapide." A part of the carbonate of lime and magnesia deposited from the water adheres to the filtering surface, and the softened water filters through it. The apparatus may be seen at work in the Exhibition.

THE PROCESS OF MESSRS. GAILLET AND HUET.

In this process, patented in February, 1883, the patentees make use of certain known agents, the patent itself applying to the apparatus used for the purpose of producing the results after the chemicals have been applied. The agents they propose are lime and caustic soda. Whenever the water contains organic matter, they use salt of alumina or iron in addition. Iron, however, is not recommended in any case where the water is required for washing purposes. The apparatus consists, virtually, of a series of tanks in duplicate, in which the chemicals are mixed, and these enter a vertical pipe in proper proportion to the water to be softened, and which communicates with the bottom of an upright chamber divided by a series of sloping shelves through which the water gradually works up in a zig-zag path. These shelves slope in one direction and are of V-shape, so that as the deposit takes place it accumulates at one point, at which there is an opening ordinarily closed by a tap, and when any tap is open the deposit on the sloping shelf communicating with it is washed out. The apparatus appears to be extremely simple in its design, but its efficiency has yet to be tested, although it is at work at Messrs. Duncan's, Victoria Docks.

PURIFICATION BY DISTILLING.

Purifying water by the process of distillation has been used from remote periods in order to produce absolutely pure water, and during the last forty years very great improvements have been adopted in order to bring this process into more general application in connection with the purposes of water supply. The difficulty of obtaining absolutely pure water is practically exemplified by this process, for in attaining this result, unless the water is distilled some two or three times, and every time a large proportion of the residue is discarded, pure water cannot be obtained. In the case, however, of water distilled for dietetic purposes, it is not necessary to carry out the process to the extent required in procuring water for some chemical purposes. It has generally been considered that distilled water lacks aeration, and on this account it has been strongly recommended that it should be filtered. The great improvements in the processes of distillation are due to Dr. Normandy, whose first patent, taken out in 1851, has been improved upon by many subsequent patents. The process has been adopted with the greatest advantage in many of our ocean steamers, and the preservation of the health of the crews and passengers visiting countries liable to the ravages of epidemic disease is, in great measure, due to this process. It is generally believed by many high sanitary authorities that if this system were adopted at malarious stations, one of the largest channels by which infection is disseminated would be effectually closed.

SOFTENING BY EXPOSURE.

The exposure to the air of water containing salts which are held by carbonic acid causes a loss of carbonic acid. Water of deep wells which has been in contact with chalk and other rocks often contains free carbonic acid by exposure, especially under the inequalities of diurnal temperature, the original charge of ground air is got rid of, and atmospheric air takes its place. On exposure to air, hard waters are especially liable to develop vegetable growth. A few days' exposure of very hard water in the summer time will soon develop green confervoid growth, and so soon as this growth takes place, carbonic acid is rapidly used up by it, so that the bicarbonates in the water are soon converted into simple carbonates, and are precipitated. Water, therefore, exposed to air undergoes a chemical metamorphosis; the bicarbonates of lime and magnesia are converted into carbon-

ates, and are precipitated, and it is in this way that exposure assists in softening water.

SOFTENING BY FREEZING.

Ice taken from hard or other impure waters, if found to be perfectly crystalline and free from air bubbles, will produce, on melting, a water as soft as that of distilled water. If, however, the ice contains air bubbles or cavities of any description, such water will not be entirely pure. Some years ago the author made an extensive series of experiments upon the degree of purity which might be arrived at by freezing water, when it was shown that the act of freezing may be carried to such an extent as to produce in the remaining water, a precipitation of the salts in solution, but ice frozen upon very superficial water was found very liable to have the impurities frozen in it which adhered to the under sides of the ice, and which became embedded in it by subsequent freezing, while water which has been largely deprived of air by boiling or exposure, upon being frozen, if perfectly crystalline, will produce absolutely pure water. Several patents have been taken out with a view to freezing sea water so as to furnish a supply of fresh water on board ship, but such processes will not compete, from an economical point of view, with the process of distillation.

GEOLOGICAL.

The geological formations which furnish water of a quality suitable to be softened are those of the dolomitic or magnesian limestone, which gives great hardness to water, for while salts of lime render water hard and troublesome in washing, those of magnesia cause the water to curdle and render it considerably more disagreeable for washing and ablution. The mountain limestone, which is ordinarily of an impermeable nature, does not yield water of such a hard quality as those of the magnesian limestone. The waters of the oolite and chalk are chiefly hard from what has been termed temporary hardness, that is due to the presence of bicarbonates of lime and magnesia in the water, which may be got rid of by boiling, or by the lime process. The waters of the new red sandstone and Permian beds vary considerably in hardness; many of them have a considerable permanent degree of hardness, but there are none of them which may not be softened to a great extent by the adoption of the lime process, while this process, in combination with the other alkali earths, such as soda, when the water is not intended to be used for dietetic and washing purposes, will still further reduce the hardness of these waters. The surface wells of the country, usually sunk in drift covering various geological formations, furnish water of various degrees of hardness. Scarcely any such wells yield a soft water, and in most instances, when these wells are sunk in populous places, in addition to their natural hardness, the waters are highly polluted, and such waters ought never to be used for dietetic purposes, unless they are first boiled.

A recent writer in the *North China Herald* discusses the part played by mercury in the alchemy and *materia medica* of the Chinese. Cinnabar was known to them in the seventh century before the Christian era, and its occurrence on the surface of the earth was said to indicate gold beneath. Their views on the transformation of metals into ores and ores into metals by heat and other means took the form of a chemical doctrine about a century before Christ, and there is now no reasonable doubt that the Arabian Geber and others (as stated by Dr. Gladstone in his inaugural address to the Chemical Society) derived their ideas on the transmutation of metals into gold and the belief in immunity from death by the use of the philosopher's stone from China. Among all the metals with which the alchemist worked, mercury was pre-eminent, and this is stated to be really the philosopher's stone, of which Geber, Kalid, and others spoke in the times of the early Caliphs. In China it was employed excessively as a medicine. On nights when dew was falling, a sufficient amount was collected to mix with the powder of cinnabar, and this was taken habitually, till it led to serious disturbance of the bodily functions. In the ninth century an Emperor, and in the tenth a Prime Minister, died from overdoses of mercury. Chinese medical books say it takes two hundred years to produce cinnabar; in three hundred years it becomes lead; in two hundred years more it becomes silver, and then by obtaining a transforming substance called "vapor of harmony" it becomes gold. This doctrine of the transformation of mercury into other metals is 2000 years old in China. The Chinese hold that it not only prolongs life, but expels bad vapors, poison, and the gloom of an uneasy mind.

MAXIMUM STRAINS IN JOINTED BOW GIRDERS.

By EMMERICH A. WERNER, C. E.

Contributed to Van Nostrand's Engineering Magazine.

External Forces in Bow Girders with Joints.

For the correct calculation of the strains in any girder, it is necessary to know the external forces acting upon it, and the greatest values they can assume.

To show how to find these external forces and their greatest values in bow girders with joints is the object of this treatise.

The external forces consist of the loads (primary forces) and the reactions of the abutments (secondary forces).

If only *vertical* reactions act upon the girder, it is called a *beam*, if *vertical and horizontal* reactions are acting, it is called a *bow girder*.

As there are only three equations expressing the equilibrium of the forces of a rigid system in the plane, it is only possible in the case of a beam on *two* supports to find the reactions of the abutments directly.—In all other cases the necessary equations for expressing the reactions of the abutments must be found by other means.—

The simplest way is the use of joints.—The joint presents no difficulty as to the construction, and gives on the other side, perfect security for correct acting.—The moments necessarily become zero in the joints

ABC represent *that line of a bow girder, in which the horizontal reaction of the abutments, or the thrust of the bow is acting.* I will call it *the line of thrust.*

The bow has joints on the abutments and in the crown. A,B are the abutment joints, C the crown joint.

Let the line ABC be referred to rectangular co-ordinates, with the origin in A.

$QQ_1H=$ be the vertical and horizontal reactions of the abutments.

$l=$ span of girder.

$f=$ ordinate of the crown joint, at the same time greatest ordinate of the bow.

$G_1G_2G_3=$ sum of all the loads from $x=o$ to $x=x$; from $x=x$ to $x=\frac{l}{2}$ and from $\frac{l}{2}$ to l.

$g_1g_2g_3=$ abscissae at the points of application of $G_1G_2G_3$.

$M_x =$ sum of the moments of all the forces in the point x.

$V_x =$ the vertical reaction of the abutment, less G_1.

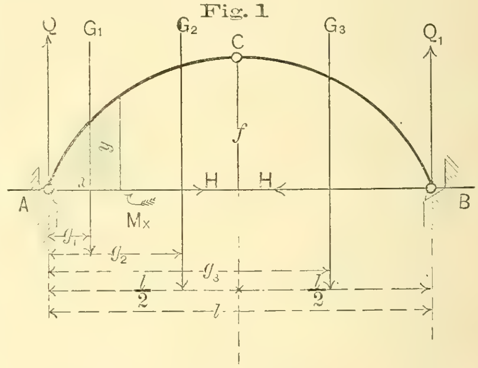
$R_x =$ sum of the shearing forces *normal* to the *line of thrust* in the point x.

$S_x =$ sum of the *vertical* shearing forces in the point x.

$\mu_x =$ angle of the tangent of the line of thrust in the point x, with the x axis.

$\mu_f =$ angle of BC or AC with the x axis.

Fig. 1



$$Q_1 = \frac{G_1g_1 + G_2g_2 + G_3g_3}{l} \quad . \quad . \quad . \quad . \quad (1)$$

$$Q = G_1 + G_2 + G_3 - Q_1$$
$$= \frac{G_1(l-g_1) + G_2(l-g_2) + G_3(l-g_3)}{l} \quad (2)$$

$$Hf = Q_1 \frac{l}{2} - G_3\left(g_3 - \frac{l}{2}\right) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$H = \frac{G_1g_1 + G_2g_2 + G_3\ (l-g_3)}{2f} \quad . \quad . \quad . \quad (4)$$

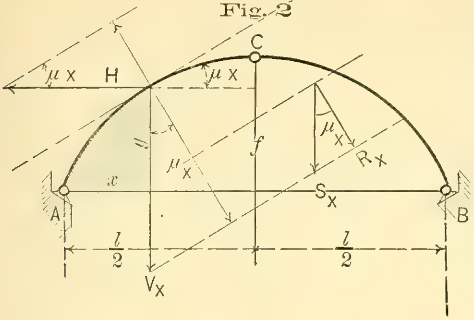
$$M_x = Qx - G_1\ (x-g_1) - Hy \quad . \quad . \quad . \quad (5)$$

$$M_x = G_1g_1\left\{1 - \frac{2fx+ly}{2fl}\right\} +$$
$$+ G_2\left\{x - g_2\frac{2fx+ly}{2fl}\right\} + G_3(l-g_3)\left\{\frac{2fx-ly}{2fl}\right\} \quad (6)$$

$$V_x = Q - G_1$$

$$R_x = \frac{dM}{ds} = V_x \cos.\ \mu_x - H \sin.\ \mu_x \quad . \quad (7)$$

Fig. 2



$$S_x = \frac{R_x}{\cos.\ \mu_x} = \frac{dM}{dx} = V_x - H \text{ tang. } \mu_x \quad (8)$$

$$S = -G_1 g_1 \left(\frac{1}{l} + \frac{\text{tang. } \mu_x}{2f}\right) + $$
$$+ G_2 \left\{1 - g_2\left(\frac{1}{l} + \frac{\text{tang. } \mu_x}{2f}\right)\right\} +$$
$$+ G_3 (l - g_3) \left(\frac{1}{l} - \frac{\text{tang. } \mu_x}{2f}\right) \quad . \ (9)$$

$$S_x = o = \frac{2f}{l} \cdot \frac{G_3(l-g_3) + G_2(l-g_2) - G_1 g_1}{G_1 g_1 + G_2 g_2 + G_3(l-g_3)} -$$
$$- \text{tang. } \mu_x \quad . \quad . \quad (10)$$

No restriction is made as to the distribution of the loads over the girder. The loads can be distributed in any way over the structure.

According to the *two* distinct kinds of loading, the disquisitions must also be divided into *two* distinct parts:

(1) for loads at rest.
(2) for moving loads.

LOADS AT REST.

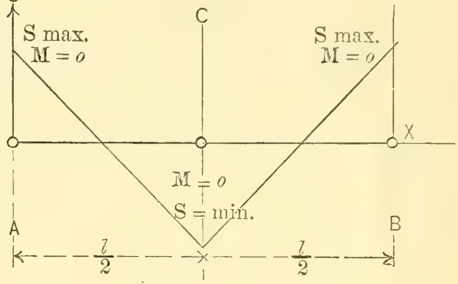
QQ_1H. = Reactions of the Abutments. They are constant. The absolute value of H is *increasing* with *decreasing* f or height of the bow.

S = Shearing Forces.

$S_x = \frac{dM}{dx}$, thus the value of S is a max. or min. in the points $M = o$ and it is zero in the points corresponding to the maximum or minimum of M. In equation 9 the first member is always negative, hence S is a maximum in $x = o$ and $x = l$ and a minimum in $x = \frac{l}{2}$, M being necessarily zero in these points in consequence of the joints. S is zero in the points corresponding to $\frac{dM}{dx} = o$.

In using x as abscissa and S_x as ordinate, the law governing the values of S can be graphically represented by a plane curve—the curve of the shearing forces. The form of that curve depends upon the form of the line of thrust and the way of loading the girder. If the line of thrust is a common parabola and the loads are equally distributed over the girder, the curve of the shearing forces are *two straight lines* as represented in Fig. 3.

Fig. 3

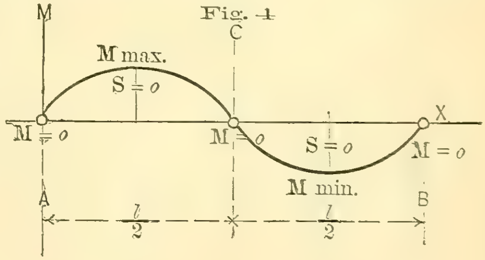


M = Moments.

The moments are zero in $x = o$ $x = \frac{l}{2}$ and $x = l$ in consequence of the joints. In the points corresponding to $\frac{dM}{dx} = o$ the values of M are maximum or minimum. The values of M increase or decrease as long as $S_x = \frac{dM}{dx}$ is positive or negative. In $x = o$ S is a maximum or positive, hence the values of the moments reach always a maximum between $x = o$ and $x = \frac{l}{2}$ and a minimum between $x = \frac{l}{2}$ and $x = l$.

If we use x as abscissa and $M_x = y$ as ordinate, the law governing the values of M will be represented by a plane curve—the curve of the moments.—The form of the curve of the moments also depends upon the form of the line of thrust and

Fig. 4



the mode of loading. If the line of thrust is a common parabola and the loads are equally distributed over the girder, Fig. 4 represents the curve of the moments.

MOVING LOADS.

The value of the external forces now depends upon x as well as upon the positions of the loads on the girder. But in first taking x=constant and only altering the positions of the loads, we obtain the variations of the forces in a point of the girder and especially the positions of the loads corresponding to the maximum and minimum values, which the forces can assume. Considering then the moving of the loads over the girder, as a series of loads at rest, it will finally be easy to apply the above derived laws and especially to define the course of the maximum and minimum values.

QQ_1H=Reactions of the Abutments.

Eqs. 1, 2, and 4 show that they are independent of x and vary only with the positions of the loads. All the members of these equations are positive and increase with G. Hence the values of QQ_1 H increase as the loads are covering the girder and reach their maximum with full loaded truss. The absolute value of H moreover *increases* with *decreasing* f or height of the bow.

M=Moments.

In equation 6—x, y being constant—the first member is always positive, as can be easily verified in writing its coefficient:

$$\left(1-\frac{2fx+ly}{2fl}\right)=\frac{l\,(f-y)+f\,(l-2x)}{2fl}.$$

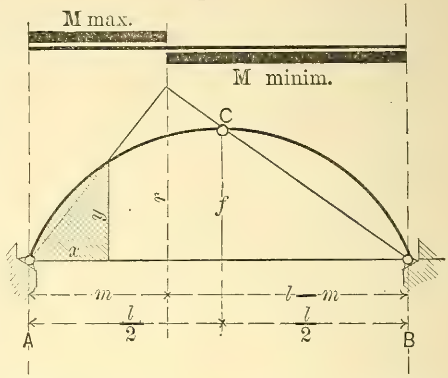
The third member:

$$G_3(l-g_3)\left(\frac{2fx-ly}{2fl}\right)=G_3(l-g_3)\frac{x}{l}\left\{\frac{f}{\frac{l}{2}}-\frac{y}{x}\right\}$$

is always negative, $\frac{f}{\frac{l}{2}}$ being the tangent of the angle of the chord AC or BC and the x axis; $\frac{y}{x}$ the tangent of the angle of Ay and the x axis.

The second member *only* can change its sign, while the loads are running over the girder. The absolute value of M thus depends from the value of this second member, increasing or decreasing as long as it is positive or negative.

Fig. 5



Hence M is a maximum or minimum, when:

$$x-g_2\frac{2fx+ly}{2fl}=o \text{ or}$$

$$g_2=\frac{2flx}{2fx+ly}=m \quad . \quad . \quad (11)$$

m can easily be graphically constructed. It is the abscissa of the intersection of the chords BC and Ay, Fig. 5. The demonstration follows directly from the figure.

Equation 11 can be put in a more convenient form for use (see Fig. 5.) It is:

$$\frac{y}{x}=\frac{f}{\frac{l}{2}}\left(\frac{l}{m}-1\right) \quad . \quad . \quad . \quad . \quad . \quad (12)$$

or in calling $\frac{y}{x}$=tang. y

$$m=l.\frac{\text{tang.}\,\mu_f}{\text{tang.}\,y+\text{tang.}\,\mu_f} \quad . \quad . \quad (13)$$

For $g_2=m$ the second member of equation (6) becomes zero. This is only possible when G_2 itself is zero. Thus $g_2=m$ represents the limit of G_1 or *that part of the x axis, which must be covered with the rolling load, to make the value of* M *a maximum or minimum.*

Values of g_2 less than m make the second member *positive*,—values greater than m make the second member *negative.*

Hence the value of M is a *maximum* when the x axis is covered from $x=o$ to

$x=m$, with rolling load, a *minimum*, when the x axis is covered from $x=m$ to $x=l$ with moving load, as represented in Fig. 5.

This rule discloses a very remarkable property of the bow girder. It shows that the maximum or minimum of M in any point of the girder depends *only* upon the form of the line of thrust and is independent of the way the loads are distributed over the girder.

In reversing the above given method, it is easy to find for any *load at rest*, that point of the girder, in which M *is a maximum or minimum.* It is sufficient to draw the chord BC and from the intersection with r—the ordinate at the end of the load—a line to A. The intersection of the latter line with the line of thrust is the point x,y in which M is a maximum or minimum according as the load covers the half-bow containing x or not.

If we now suppose for every point in the girder the positions of the rolling load, corresponding to the maximum and minimum of M, constructed in the above way, we shall have a series of loads at rest on which the rules for the latter can be applied.

Thus the maximum or minimum value of M themselves must be zero in $x=o$; $x=\frac{l}{2}$ and $x=l$. They will increase or decrease, with increasing x, as long as $\frac{dM}{dx}=S_x$ is positive or negative. Eq. (9):

$$S_x=-G_1g_1\left(\frac{1}{l}+\frac{\text{tang. }\mu_x}{2f}\right)+$$
$$+G_2\left(1-g_2\frac{\text{tang. }\mu_x}{2f}\right)+$$
$$+G_3(l-g_3)\left(\frac{1}{l}-\frac{\text{tang. }\mu_x}{2f}\right)$$

changes its sign, when

$$\frac{1}{l}-\frac{\text{tang. }\mu_x}{2f}=o$$

or in the point x,y corresponding to

$$\text{tang. }\mu_x=\frac{f}{\frac{l}{2}}=\text{tang. }\mu_f \quad . \quad . \quad . \quad . \quad (14)$$

The point x,y, in which the maximum and minimum of the moments become an *absolute maximum and minimum, is thus the point of contact of a tangent to the line of thrust parallel with the chord AC or BC.*

In applying at that point the construction for maximum and minimum of M, it is easy to find the positions of the rolling load corresponding to the *absolute* maximum and minimum values of M in the girder.

This position is also independent of the mode of loading and only depends upon the form of the line of thrust. This fact can be verified in another way:—The absolute maximum and minimum being independent of $G_1G_2G_3$, tang. $\mu_x=\frac{f}{\frac{l}{2}}$ must be a root of the equation $S=o$, whatever be $G_1G_2G_3$. This is indeed the case, as it is easy to ascertain from equation (10)

$$o=\frac{f}{\frac{l}{2}}\cdot\frac{G_3(l-g_3)+G_2(l-g_2)-G_1g_1}{G_1g_1+G_2g_2+G_3(l-g_3)}-$$
$$-\text{tang. }\mu_x$$

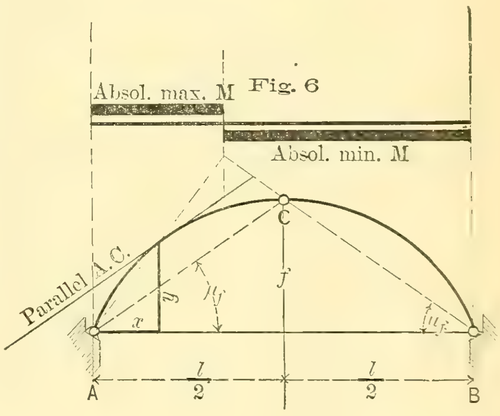


Fig. 6 shows the graphical construction of the point corresponding to the absolute maximal and minimal values of M.

S=Shearing Forces.

In equation (9) $-x,y$ being constant.—

$$S_x=-G_1g_1\left(\frac{1}{l}+\frac{\text{tang. }\mu_x}{2f}\right)+$$
$$+G_2\left\{1-g_2\left(\frac{1}{l}+\frac{\text{tang. }\mu_x}{2f}\right)\right\}+$$
$$+G_3(l-g_3)\left(\frac{1}{l}-\frac{\text{tang. }\mu_x}{2f}\right) \quad (9)$$

the coefficient of the *first* number is always positive.

The coefficient of the *third* member, or

$$\left(\frac{1}{l}-\frac{\text{tang. }\mu_x}{2f}\right)=\frac{1}{2fl}\left\{\frac{\frac{f}{l}}{\frac{}{2}}-\text{tang. }\mu_x\right\}$$

is positive or negative according as

$$\text{tang. }\mu_x \gtrless \frac{\frac{f}{l}}{2}$$

Hence if

$$\text{tang. }\mu_x > \frac{\frac{f}{l}}{2}$$

or for points between $x=o$ and the point corresponding to the absolute maximum of M, that is

$o<x<x$ corresponding abs. max. M.

The *first and third* member of equation (9) is *negative*, and if

$$\text{tang. }\mu_x < \frac{\frac{f}{l}}{2}$$

or for points between the point corresponding to the absolute maximum of M and the crown joint, that is

x corresponding abs. max. $M<x<\frac{l}{2}$

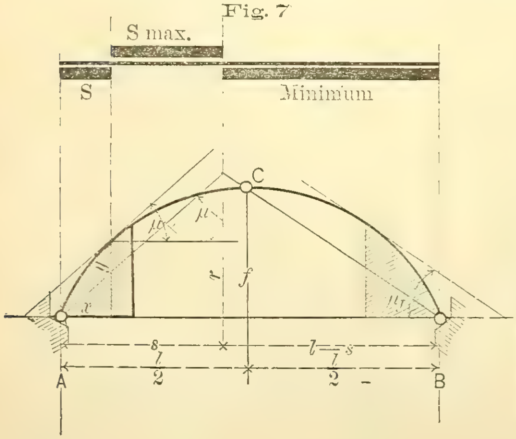
the *first* member is negative and the *third* positive.

The *second* member changes its sign when

$$g_2=\frac{2fl}{2f+l\text{ tang. }\mu_x}=s \quad . \quad . \quad (15)$$

s can be graphically constructed. It is the abscissa of the intersection of the

Fig. 7



chord BC and a line from A *parallel with the tangent in point x,y.*

The demonstration follows directly from the figure.

A more convenient form of s for use is the following:— (see Fig. 7.)

$$\text{tang. }\mu_x=\frac{\frac{f}{l}}{2}\left(\frac{l}{s}-1\right) \quad . \quad . \quad (16)$$

$$s=l.\frac{\text{tang. }\mu_f}{\text{tang. }\mu_x+\text{tang. }\mu_f} \quad . \quad . \quad . \quad (17)$$

s represents for reasons shown already by the moments, the limit of G_1, or *that part of the x axis, which must be covered with moving load to make* S *a maximum or a minimum.*

Values of g_2 *less* than s makes the *second* member of equation (9) *positive*, values *greater* than *s negative.* Hence, when

$$\text{I} \quad \text{tang. }\mu_x > \frac{\frac{f}{l}}{2} \text{ or,}$$

$o<x<x$ corresponding abs. max. M.

the *first and third* member of equation (9) being *negative*:

S is a maximum, when the parts of the girder corresponding to G_1 and G_3 are empty, or when the girder is covered with load from $x=x$ to $x=s$, and

S *is a minimum*, when the girder is covered with loads from $x=o$ to $x=x$ and *at the same time* from $x=s$ to $x=l$.

$$\text{II} \quad \text{tang. }\mu_x < \frac{\frac{f}{l}}{2} \text{ or,}$$

x corresponding abs. max. $x<x<\frac{l}{2}$

For tang. $\mu_x \underset{=}{<} \frac{\frac{f}{l}}{2}$, s becomes $=\frac{l}{2}$ and the *second* member of equation (9) is *positive*, leaving only the *first* member *negative*; thus:—

S *is a minimum*, when the parts of the girder corresponding to G_2 and G_3 are covered with load, or when the girder is covered from $x=x$ to $x=l$, with rolling load.

S *is a minimum*, when the girder is loaded from $x=o$ to $x=x$.

Fig. 7 shows the graphical construction of the positions of the loads for S max.

and S min., when tang. $\mu_x > \frac{f}{\frac{l}{2}}$ and Fig. 8, the same when tang. $\mu_x < \frac{f}{\frac{l}{2}}$

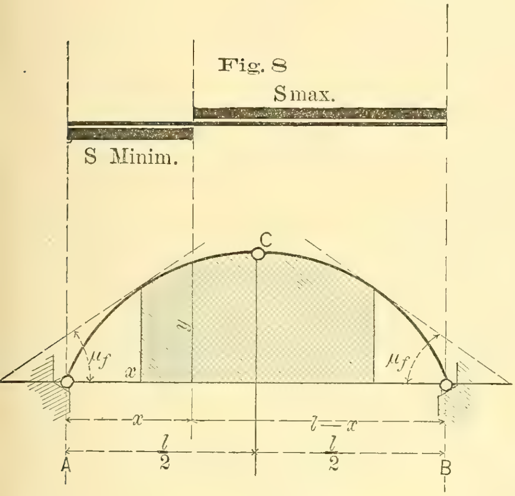


Fig. 8

Generally the loads will be concentrated in certain points of the girder—the panel points—and in constructing the positions of the loads corresponding to the maximum and minimum of M and S the beginning and end of m and s will fall either between two panel points or *coincide* with a panel point itself, and the question arises, how far the loads must in each case cover the girder to produce the maximum or minimum values.

If the end of m or s falls between *two* panel points, the answer presents no difficulty. i and $(i+1)$ be the two points, then evidently m or s will be covered completely with moving load, if the girder is covered from $m=o$ or $s=o$ to the point i (inclusive) and $(l-m)$ or $(l-s)$ will be completely loaded, when the girder is covered from $(i+1)$ including this point to l and it will be easy in each case to find the positions of the moving loads corresponding to a maximum or minimum.

Not so, if the beginning or end of m or s coincides with a panel point itself. It is then impossible *a priori* to decide whether the point must be covered with load or not to produce M or S maximum or minimum, but a decision can be reached in the following way:

I begin with s the value governing the maximum and minimum of S the shearing forces, and we must bear well in mind, that S is *not* acting in *a point*, but as well as tang. μ_x in the *whole panel*.

I.

The Beginning of S Coincides with a Panel Point.

Fig. 9 represents the positions of the rolling load with regard to the panel x.

P=be the sum of all the moving loads acting upon the girder.

a=coefficient expressing the ratio of P to Q_1.

b=that part of P forming with $Q_1 \frac{l}{2f}$ the thrust H.

$\alpha, \beta, \gamma, \triangle$ panel lengths.

p, p_1=loads in different panel points.

Note. P, a, b are of different value for each position of the loads, but as no mistake is possible, no especial letters have been used.

The other letters have the previous significations.

Fig. 9 a=The loads cover the girder from the point $(x-\alpha)$ to any point towards B and again from the point x to the same point towards B. It is:

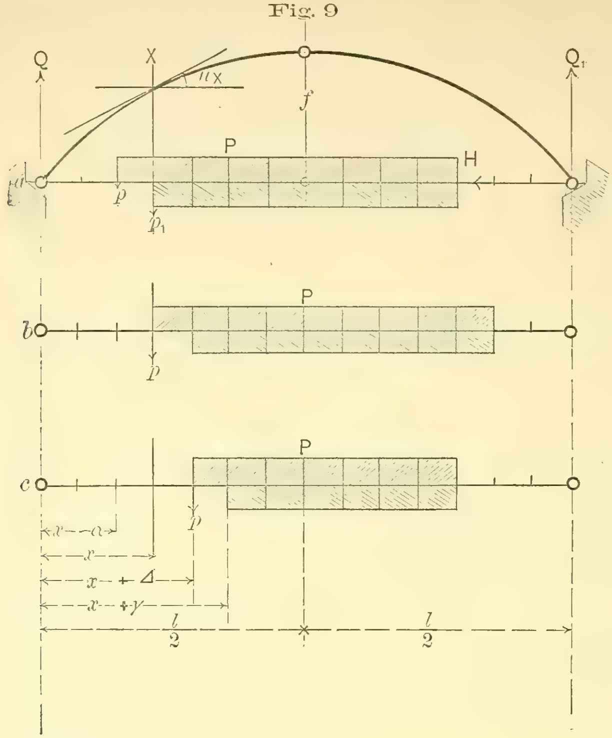
$(x-\alpha)$	(x)
$Q_1^{x-\alpha} = aP.$	$Q_1^x = aP - \left(\frac{x-\alpha}{l}\right)p$
$Q^{x-\alpha} = P - Q_1^{x-\alpha}$	$Q^x = P - p - Q_1^x$
$H^{x-\alpha} = Q_1^{x-\alpha}\frac{l}{2f} - b$	$H^x = Q_1^x \frac{l}{2f} - b$

AND

$$S_x^{x-\alpha} = P - Q_1^{x-\alpha} - p - p_1 - Q_1^{x-\alpha}\left(\frac{l}{2f}\text{tang. }\mu_x\right) - b\text{ tang. }\mu_x = P - \left\{Q_1^{x-\alpha}\left(1 + \frac{l}{2f}\text{tang. }\mu_x\right) + b\text{ tang. }\mu_x + p + p_1\right\}$$

$$S_x^x = P - Q_1^x - p - p_1 - Q_1^x\left(\frac{l}{2f}\text{tang. }\mu_x\right) - b\text{ tang. }\mu_x = P - \left\{Q_1^x\left(1 + \frac{l}{2f}\text{tang. }\mu_x\right) + b\text{ tang. }\mu_x + p + p_1\right\}$$

Fig. 9



HENCE:

$$S_x^{x-a} < S_x^x \text{ when}$$

$$Q_1^{x-a} > Q_1^x \text{ or}$$

$$\frac{x-a}{l} > o$$

Fig. 9 *b*=The loads cover the girder from the point x and again from $(x+\triangle)$. It is:

$$S_x^x < S_x^{x+\triangle} \text{ when:}$$

$$Q_1^x > Q_1^{x+\triangle} \text{ or}$$

$$\frac{x}{l} > o$$

Fig. 9 *c*—The loads cover the girder from the point $(x+\triangle)$ and again from $(x+\gamma)$. It is:

$$S_x^{x+\triangle} < S_x^{x+\gamma} \text{ when:}$$

$$\text{tang. } \mu_x > \frac{\frac{f}{l}}{\frac{}{2}}\left(\frac{l}{x+\triangle}-1\right) \text{or} \quad . \quad . \quad (18)$$

$$\frac{\text{tang. } \mu_x}{\frac{l-(x+\triangle)}{(x+\triangle)}} > \frac{\frac{f}{l}}{2} \quad . \quad . \quad (19)$$

Recapitulating we find, that *always*

$$S_x^{x-a} < S_x^x < S_x^{x+\triangle} >_x^{x+\gamma} \quad . \quad . \quad (20)$$

The first two conditions result directly from the above equations. The last one:

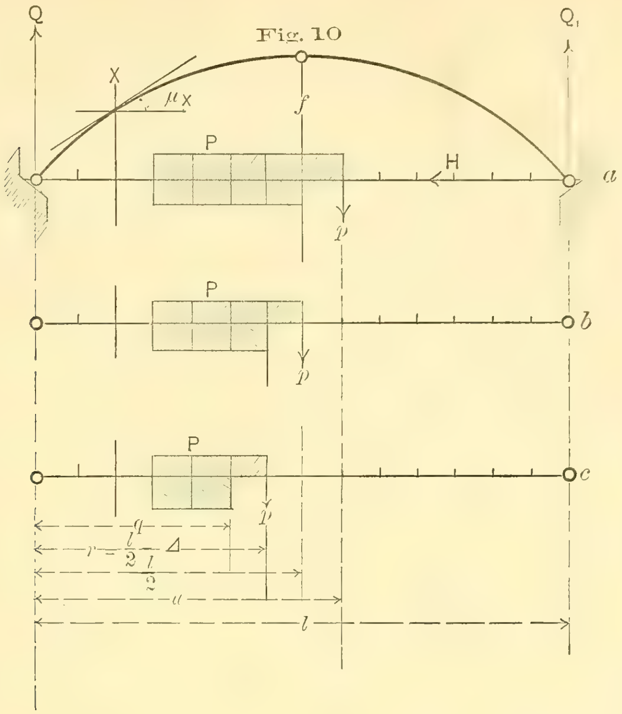
$$S_x^{x+\triangle} > S_x^{x+\gamma}$$

is demonstrated as follows:

Equation 18 shows that tang. μ_x must be $> \frac{\frac{f}{l}}{2}$ to have $S^{x+\triangle} < S_x^{x+\gamma}$. This is the case only in panels between $x=o$ and the x corresponding to the abs. maximum or minimum of the moments. Hence it is only necessary to take panels in consideration from $x=o$ to x=abs. maximum or minimum of M. But it is evident, that in this part of the line of thrust, tang. μ_x is a max. when x is as small as possible. Thus considering the first panel of the girder we shall have tang. μ_x=max. The value of tang. μ_x in the first panel is:

$$\text{tang } .\mu_x = \frac{y}{x+\triangle}$$

Fig. 10



Using this value in equation 19, we find

$$\frac{y}{l-(x+\Delta)} > \frac{f}{\frac{l}{2}}$$

but as y is always $<f$ and $[l-(x+\Delta)] > \frac{l}{2}$ the above inequality can never be fulfilled and we find equation (20). The equation (20) shows that for S_x *max. in panel* x, the loads *always begin in* $(x+\Delta)$, while for S *min. in panel x*, the loads *always cover the point x*.

II.

The End of S Coincides with a Panel Point.

Fig. 10 represents the positions of the loads with regard to the panel x and the crown joint, in the vicinity of which the end of s falls always.

Fig. $10a$=The girder is covered from $(x+\Delta)$ to u, and again to $\frac{l}{2}$ with moving loads. It is

u	$\frac{l}{2}$
$Q_1^u = aP$	$Q_1^{\frac{l}{2}} = aP - \frac{u}{l}p$
$Q^u = P - Q_1^u$	$Q^{\frac{l}{2}} = P - p - Q_1^{\frac{l}{2}}$
$H^u = Q_1^u \frac{l}{2f} - p\left(\frac{2u-l}{2f}\right)$	$H^{\frac{l}{2}} = Q_1^{\frac{l}{2}} \frac{2f}{l}$

and

$$S_x^u = P - \left\{ Q_1^u \left(1 + \frac{l}{2f} \text{tang. } \mu_x\right) - \right.$$
$$\left. -p\left(\frac{2u-l}{2f} \text{tang. } \mu_x\right) \right\}$$

$$S_x^{\frac{l}{2}} = P - \left\{ Q_1^{\frac{l}{2}} \left(1 + \frac{l}{2f} \text{tang. } u_x\right) + p \right\}$$

hence,

$$S_x^u < S_x^{\frac{l}{2}} \text{ when}$$

$$\text{tang. } \mu_x > \frac{f}{\frac{l}{2}} \quad . \quad . \quad . \quad (21)$$

Fig. 10 b=The loads cover the girder

from $(x+\triangle)$ to $\frac{l}{2}$ and again to r. It is

$$S_x^{\frac{l}{2}} < S_x^r \text{ when}$$

$$\text{tang. } \mu_x > \frac{f}{\frac{l}{2}} \quad . \quad . \quad . \quad (22)$$

Fig. 10 c=The loads cover the girder from $(x+\triangle)$ to r and again to t. It is—

$$S_x^r < S_x^t \text{ when}$$

$$\text{tang. } \mu_x > \frac{f}{\frac{l}{2}}\left(\frac{l}{r}-1\right) \quad . \quad . \quad . \quad (23)$$

If tang. μ_x is *exactly* $\frac{f}{\frac{l}{2}}$, equations (21) and (22) give—

$$S_x^l = S_x^{l-1} = \;.\;.\; = S^{\frac{l}{2}} = S_x^{r=(\frac{l}{2}-\triangle)}$$

or S maximum is reached in the panel corresponding to tang. $\mu_x = \frac{f}{\frac{l}{2}}$, by loading the girder from $(x+\varDelta)$ to *any* point *between* $r=\left(\frac{l}{2}-\triangle\right)$ and l. But, though the maximum of S is reached by any one of the above positions, the strains induced in the members of the girder are not the same for each of the mentioned positions, as will be shown when we shall consider the strains in the members, and with regard to the maximum of the *strains in the members* of the girder, S *is a maximum*, when the girder is loaded from $(x+\triangle)$ to r or to $\left(\frac{l}{2}-\triangle\right)$

Equation (23) shows further that, if tang. μ_x is exactly $\frac{f}{\frac{l}{2}}\left(\frac{l}{r}-1\right)$

$$S_x^r = S_x^{(r-\triangle)=t}$$

or that the girder may as well be loaded, say, to r as to $(r-\varDelta)$ to obtain S maximum in the panel corresponding to

$$\text{tang. } \mu_x = \frac{f}{\frac{l}{2}}\left(\frac{l}{r}-1\right)$$

Accordingly, S minimum would begin either with r or with $(r+\varDelta)$. But only the last position of the loads will produce S minimum. Hence, though S maximum may be reached, in the above special case, in the mentioned *two* ways, S is a maximum, with regard to the minimum, when the girder is covered to r, and not to $(r-\varDelta)$ with load.

Recapitulating, and assuming S to be a *maximum*, we find that the end of s never *extends beyond* $\left(\frac{l}{2}-\varDelta\right)$. But s can become *less* than $\left(\frac{l}{2}-\varDelta\right)$, according to the form of the line of thrust. The end of s will extend *only* to the following points, or the rolling loads will cover the girder only to the point—

t (inclusive) when tang. $\mu_x > \frac{f}{\frac{l}{2}}\left(\frac{l}{r}-1\right)$

y (inclusive) when tang. $\mu_x > \frac{f}{\frac{l}{2}}\left(\frac{l}{t}-1\right)$

and so-forth.

If the panels are of equal length and $2n$ is their number—the loads may be different in each one—then the loads *cover the girder to the point*, including this point:—

$$\left(\frac{l}{2}-2\right)\text{when : tang. } \mu_x > \frac{f}{\frac{l}{2}}\left(\frac{n+1}{n-1}\right) \quad . \quad (24)$$

$$\left(\frac{l}{2}-3\right)\text{when tang. } \mu_x > \frac{f}{\frac{l}{2}}\left(\frac{n+2}{n-2}\right) \quad . \quad (25)$$

and so-forth.

For S *minimum*, $(l-s)$ *always* begins with the point *following* the end of s.

The equations (21) to (25) are simply applications of the general equation (16).

The shearing forces in the first panel and the panel containing the crown joints, are:—

$$S_I = \frac{+M^I}{-\varDelta} \text{ and}$$

$$S_{\frac{l}{2}} = \mp \frac{M_{\left(\frac{l}{2}-\varDelta\right)}}{\varDelta}$$

and their maximum and minimum depends upon the positions of the loads corresponding to M_I and $M_{\left(\frac{l}{2}-\varDelta\right)}$ maximum and minimum.

We now turn to m, the length of the x axis governing the maximum and minimum of the moments.

We shall consider m corresponding to M maximum.

The beginning of m always lies in $x=o$ and nothing special is to be remembered.

The End of m Coincides with a Panel Point.

Equation (13):—

$$m = l . \frac{\text{tang, } \mu_f}{\text{tang. } y + \text{tang. } \mu_f}$$

is exactly the same as equation 17.

$$s = l . \frac{\text{tang. } \mu_f}{\text{tang. } \mu_x + \text{tang. } \mu_f}$$

when we substitute tang. y for tang. μ_x and the deductions from equation (17), will also hold good for equation (13).

Hence, if the end of m coincides with a panel point, say r, it will not alter the absolute value of M maximum, when the girder is covered either to r or to $(r-\varDelta)$, but, as by s, with regard to the minimum, M is a maximum, when the girder is loaded to r and not to $(r-\varDelta)$. Concerning the *absolute* maximum or minimum of M, it is necessary to bear in mind, that the criterion is bound to tang. μ_x, and that tang. μ_x means not a point, but a whole panel.

In case of M minimum, $(l-m)$ always begins with the next point *following the end of m.*

Before I now proceed to show by an example how plain the application of these rules is in reality, I will recapitulate them in few words.

Moments.

Draw in any point x,y, Ay and BC—see Fig. 5.—The intersection of these lines lies in the panel point m or between

m and $m+\varDelta$, and it will be in the point x,y:

M *a maximum,* when from o to inclusive point m.

M *a minimum,* when from inclusive point $(m+\varDelta)$ to l the girder is covered with loads.

Draw a tangent to the line of thrust *parallel* with the chord AC or BC. The point of contact gives the point of abs. maximum or minimum of M—see Fig. 6.

Shearing Forces.

I. Panels in which tang. $\mu_x \geqq \frac{f}{\frac{l}{2}}$, or

$o < x < x_2$ corresponding abs. max. M

Draw BC and from A a line *parallel* with tang. x, y—see Fig. 7.—The intersection of both lines lies in the panel point s or between s and $(s+\varDelta)$ and it will be in the panel x.

S *a maximum,* when from inclusive point $(x+\varDelta)$ to inclusive point s.

S *a minimum,* when from o to inclusive point x and at the same time from inclusive point $(s+\varDelta)$to l the girder is covered with loads.

II. Panels, in which tang. $\mu_x < \frac{f}{\frac{l}{2}}$ or

x correspond. abs. *maximum* $M < x < \frac{l}{2}$

Note.—The tang. μ_x *must be smaller than* $\frac{f}{\frac{l}{2}}$—see Fig. 8.—

In the panel x, it will be:

S *a maximum,* when from inclusive point $(x+\varDelta)$ to l.

S *a minimum,* when from o to inclusive point x the girder is covered with loads.

S_I and $S_{\frac{l}{2}}$ have their maxima and minima with M_I and $M_{\left(\frac{l}{2}-\varDelta\right)}$ max. or min.

If calculation is preferred, calculate:

1. tang. μ_x in the panels I to $\frac{l.}{2}$

The nearest value of tang. μ_x to $\frac{f}{\frac{l}{2}}$

gives the panel of the absolute max. or min. of M.

2. Calculate m from equation 13 for each panel point and proceed as shown previously.

3. Calculate s from equation 17 and proceed as shown above.

I use both methods together, generally employing the graphical method and the calculation only, where the end of m or s falls so near a panel point, that a sharper definition is wanted.

It is hardly necessary to say, that to the effects of the rolling loads must be added the effect of any load at rest.

EXAMPLE.

Figure 11 represents the line of thrust of a girder of 150′ span. It has 10 panels of 15′ length. f is 30′. The line of thrust is a common parabola. The own weight is assumed to 18,000 lbs. per panel, the rolling load to 45,000 lbs. per panel.

QQ_1H.

It is *only necessary* to calculate the reactions of the own weight and for the moving loads, the values corresponding to the successive positions from $x=o$ to $x=\frac{l}{2}$ and for full loaded girder. All other values are found by addition or subtraction as shown, by M minima.

Own weight $=Q^E=Q_1{}^E=81000$ lbs.

Own weight $=H^E=112500$ lbs.

ONLY MOVING LOADS.—$Q_1{}^N Q^N H^N$.

Loaded from point o to point—	$\overset{N}{Q_1}$.	$\triangle_1$.	$\triangle_{11}$.	$\overset{N}{Q}+\overset{N}{Q_1}$.	$\overset{N}{Q}$.	$\overset{N}{H}$.	
0 to 1	$4500=\frac{1}{10}$	9000		45000	40500	11250	$f\,H=Q_1\frac{l}{2}$
0 to 2	$13500=\frac{3}{10}$	13500	4500	90000	76500	33750	$H=2.5\,Q_1$.
0 to 3	$27000=\frac{6}{10}$	18000	4500	135000	108000	67500	
0 to 4	$45000=\frac{10}{10}$	22500	4500	180000	135000	112500	
0 to 5	$67500=\frac{15}{10}$			225000	157500	16875	

Full load $=Q^N=Q_1{}^N=202500$ lbs.

Full load $=H^N=281250$ lbs.

In these and the following calculations much time and labor can be saved, in using instead of the panel length, the ratio of this length to the span—here $\frac{1}{10}$. It is then $Q_1{}^{(o-1)}=1\times\frac{p}{10}$, $Q_1{}^{(o-2)}=(1+2)=3\times\frac{p}{10}$, . . . and the calculation of Q_1 for the different positions of the moving loads is reduced to a multiplication of $Q_1{}^{(o-1)}$ with the sum of the panel indices of the loaded panels, as shown above, or

$$\frac{1\,.\,2\,.\,3\,.\,4\,.\,5\,.\,.\,.}{1\quad 3\quad 6\quad 10\quad 15}\quad \begin{matrix}\text{panel indices}\\ \text{coefficients}\end{matrix}$$

The correctness of the calculation can moreover be easily verified, the values of Q_1 forming a higher arithmetical seria, which is shown above.

For calculation of H *use equation* 3, for instance:

Full loaded $H^N=$

$$=\frac{202500\times5-45000\times10}{2}=281250 \text{ lbs.}$$

MOMENTS.

Use equation 5 *for calculation*—

—See Fig. 11*b*—

Draw BC and Ay in each panel point.

Maxima—

for M_1 and M_2 *loaded from o to point* 3

Q=189,000 lbs. H=180,000 lbs.

for M_3 and M_4 *loaded from o to point* 4

Q=216,000 lbs. H=225,000 lbs.

$M_1=+89100$ f. lbs.

$M_2=+(189{,}000\times15)\times2-63{,}000\times15-$
$-180{,}000\times19'2=+1{,}269{,}000$ f. lbs.

$M_3=+1{,}215{,}000$ f. lbs.

$M_4=+810{,}000$ f. lbs.

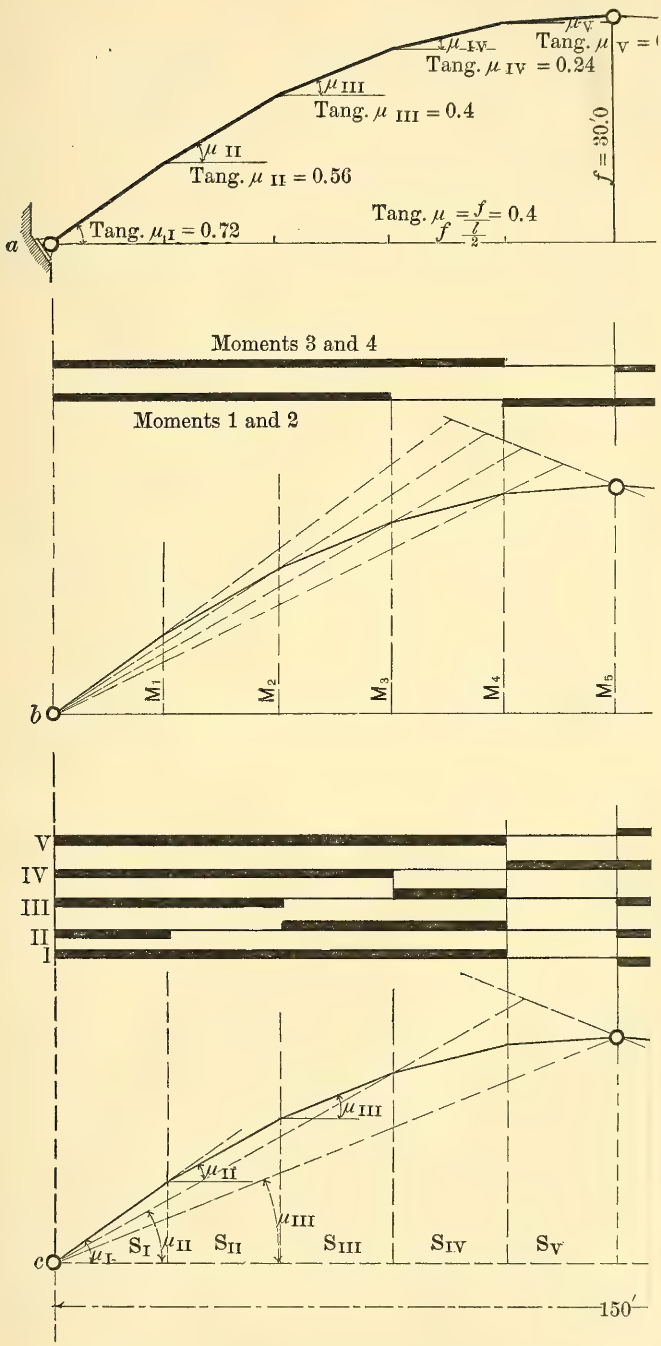
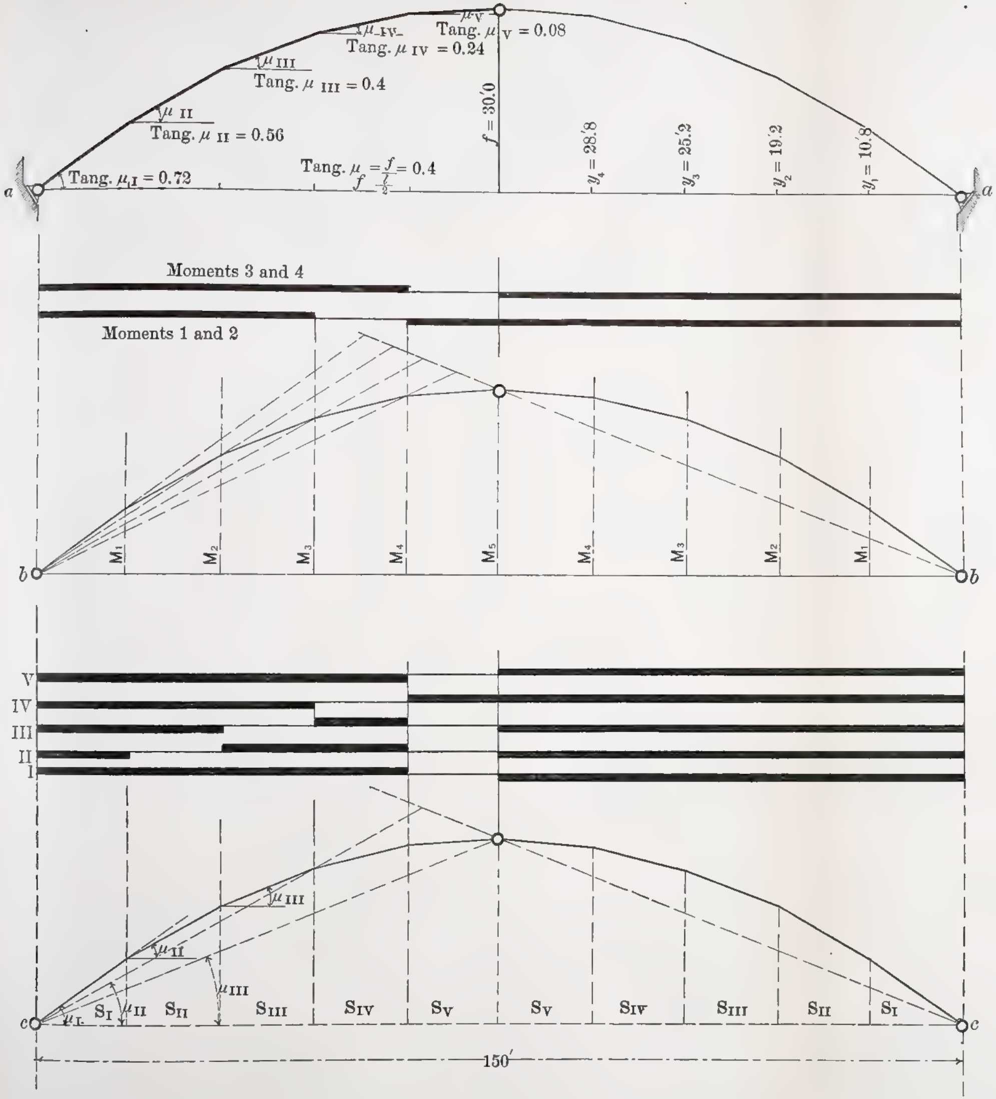


Fig. 11
Tang. μ_{V} =
Tang. μ_{IV} = 0.24
Tang. μ_{III} = 0.4
Tang. μ_{II} = 0.56
Tang. μ_{I} = 0.72
Tang. $\mu_f = \frac{f}{\frac{l}{2}} = 0.4$
f = 30.0
Moments 3 and 4
Moments 1 and 2
M_1 M_2 M_3 M_4 M_5
V IV III II I
S_I S_{II} S_{III} S_{IV} S_V
150′

Fig. 11



Tang. μ_V = 0.08
Tang. μ_{IV} = 0.24
Tang. μ_{III} = 0.4
Tang. μ_{II} = 0.56
Tang. μ_I = 0.72
Tang. $\mu_f = \frac{f}{\frac{l}{2}}$ = 0.4
f = 30.0
y_4 = 28.8
y_3 = 25.2
y_2 = 19.2
y_1 = 10.8
Moments 3 and 4
Moments 1 and 2
M_1 M_2 M_3 M_4 M_5 M_4 M_3 M_2 M_1
V
IV
III
II
I
S_I S_{II} S_{III} S_{IV} S_V S_V S_{IV} S_{III} S_{II} S_I
150′

Minima.

for M_1 and M_2 *loaded from* 4 *to* 10.

	lbs.		lbs.
$Q^{N(0-10)}$	$=202{,}500$	$H^{N(0-10)}$	$=281{,}250$
$Q^{N(0-3)}$	$=108{,}000$	$H^{N(0-3)}$	$=67{,}500$
$Q^{N(4-10)}$	$=94{,}500$	$H^{N(4-10)}$	$=213{,}750$
Q^{E}	$=81{,}000$	H^{E}	$=112{,}500$
$Q^{(4-10)}$	$=175{,}000$	$H^{(4-10)}$	$=326{,}250$

for M_3 and M_4 *loaded from* 5 *to* 10,

$Q=148{,}500$ lbs. $H=281{,}250$ lbs.

$$M_1=-\ 891{,}000 \text{ f. lbs.}$$
$$M_2=-1{,}269{,}000 \text{ f. lbs.}$$
$$M_3=-1{,}215{,}000 \text{ f. lbs.}$$
$$M_4=-\ 810{,}000 \text{ f. lbs.}$$

SHEARING FORCES.

—(see Fig. 11*c*.)—

Use equation 8 *for calculation*—

Draw BC and the lines *parallel* to the corresponding tangent in each panel.

Maxima.

$$S=\frac{M_1 \text{ max.}}{\varDelta}=+59{,}700 \text{ lbs.}$$

S_{ii} loaded 2—4. $H=213{,}750$

$Q=175{,}500$ H tang. $\mu_{ii}=213{,}750\times0.56$

$p=\ 18{,}000$ $\quad$ 119,700 lbs.

$157{,}500=V_{II}$

$119{,}700=H \text{ tang.} \mu_{II}$

$+37{,}800$ lbs.

S_{iii} loaded 3—4

$+27{,}000$ lbs.

S_{iv} loaded 4—10

$+43{,}200$ lbs.

S_v loaded 5—10 $=\dfrac{M_4}{\varDelta}$

$+54{,}000$ lbs.

Minimum.

$$S_i=-\frac{M_1}{\varDelta}=-59{,}400 \text{ lbs.}$$

S_{ii} loaded 0—1 & 5—10 $=-37{,}800$ lbs.

S_{iii} loaded 0—2 & 5—10 $=-27{,}000$ lbs.

S_{iv} loaded 0—3 $=-43{,}200$ lbs.

S_v loaded $0-4=\dfrac{M_4}{\varDelta}=-54{,}000$ lbs.

With the knowledge of the external forces, the calculation of the strains in members of the girder is subject to no difficulty, as I will show later.

CO-OPERATION BETWEEN NATIONAL AND STATE GOVERNMENTS IN TOPOGRAPHICAL SURVEYS.

BY H. F. WALLING.

Read before the American Society of Civil Engineers at the Buffalo Meeting.

WHILE it is known by civil engineers and other well-informed persons that good topographical surveys are among the necessities of nations for the economical construction of public works and for other useful purposes, this knowledge does not appear to be shared by the people in general, or by their legislators. Our widely extended and comparatively new country, now fairly entered upon its second century of national existence, although in many respects quite as advanced as the older European nations, has, much to its disadvantage, allowed itself to be outstripped by them in this matter.

Among the primary uses to which topographical surveys are put is their guidance in the location of railways and other avenues of internal communication, the abundance and efficiency of which afford to the political economist the most reliable measures of the comparative prosperity of different countries or portions of the same country. The relation between this prosperity and the construction of railways and other public works becomes one of recurring action and reaction, and the effects are accumulative. The public works cause an increase of prosperity which in turn calls for more public works, and so on almost indefinitely. With good topographical maps the best location for a road or railway is readily determined by a careful inspection of the map, and much of the uncertainty

as well as the expense of preliminary surveys is avoided.

In Great Britain, for example, when a new railway is proposed, the best route is first sought by a careful examination of the "Ordnance Maps," upon which exhaustive comparisons of all possible routes can be made as to grades, curves, excavations, embankments, etc., and from the data thus obtained the preferable location can be chosen. The "Parliamentary map" has this selected line laid down upon sheets of the ordnance map, where it can be intelligently considered by a parliamentary committee before legal authority is granted for building the road.

This preliminary map does not usually differ essentially from the more exact map of final location, and the cost of building the road, after so careful a selection of the route, is likely to be as small as possible. Most of the railways of our own country, unfortunately, were constructed without such a valuable preliminary guide and the result has been marked by great waste. It has been estimated by a railway engineer, a friend of the writer, that had the State of Massachusetts been in possession of a good topographical map in 1836, some $20,000,000 would probably have been saved in its public railway expenditures. While it is too late, as he says, to recall the $20,000,000 of unremunerative investments, it is not too late by means of a good survey, to guide private and corporate capital in the economical development hereafter of the various public works which will be demanded by the growing commonwealth.

If a cause be sought for the failure in this country to carry out a measure of obviously wise economy, in which every country in Europe has led the way, with the approbation of all their intelligent citizens, it is to be found, partially at least, in the peculiarities of our form of government, limited to matters of national safety, commerce with foreign nations, management of public property and certain inter-state relations which are regulated under the appropriate departments of the government.

A strong sentiment has prevailed from the outset against any extension of the general government, and up to the present time no direct national legislation has authorized a topographical survey of the country.

In the meantime State legislatures have been slow to see the need of costly surveys and they have been undertaken in but a very few of the States. In some of these, creditable work has been commenced, but in none has it been brought to completion. The State of Massachusetts took the lead in 1829-30 when resolves were passed by the General Court requiring each town in the commonwealth to forward to the Secretary's office an accurate map of its territory on a scale of 100 rods to an inch (nearly 1:20,000). In accordance with subsequent legislation a trigonometrical survey of great excellence was completed in 1838 and the town surveys, after a much needed revision and correction were fitted into the framework of the triangulation. The result was a very good map of the State, the best of its kind indeed that has been made of any of the United States up to the present time. It was drawn upon the scale of two-fifths of an inch to a mile (1:158,400) and engraved on copper. The geographical positions of the sea coast, rivers, streams, lakes, roads, railways, town boundaries, villages, etc., were given with commendable accuracy. The smallness of the scale, however, while permitting the use of the map in one connected sheet, which may conveniently hang on the wall, greatly limits the other uses to which it may be put.

Moreover, the map lacks an important feature, needed to bring it up to the standard of the best of the more modern European maps, and to make it available for engineering requirements, namely, the accurate expression of the vertical relations between the objects represented, in other words their heights above a standard level. Borden's survey determined the heights of most of his primary stations above the level of the sea, and these heights are marked upon the map. But the only other indication of difference of level is by an imperfect system of hachures, which, while attempting to indicate the direction and steepness of slopes, fails to show the differences of level, quantitatively or even qualitatively, except between adjacent areas. The inadequacy of the most perfect system of hachures to intelligently represent quantitative hypsometric relations may be seen

by consulting the best maps constructed in that manner. Among these are some of the official maps, already mentioned, of European countries, which are exceedingly beautiful as pictures, or samples of fine engraving, but fail entirely to convey definite hypsometric information. Practical good sense however seems likely to prevail over that conservative tenacity which opposes even the most obvious reforms and the elaborate hachure systems of Lehman and others are falling into disuse, especially upon maps of large scale and corresponding minuteness of detail.

Lines of equal surface elevation or "*contour lines*," as they are called, if accurately drawn, are much more effective in showing, not only the great general features, but the minute details of height inequalities, and if delicately indicative lights and shadows accompany the contour lines, the general relief of the country may be made to appear at a glance, while the absolute heights can everywhere be ascertained by easy inspection. The intervals of level between these contour lines must be determined in relation to the scale of the map and the amount of elaboration intended.

Although no complete surveys of the scope indicated above have been made by State authorities, . . . (The United States Geological Survey has completed a topographical and geological map of the State of Colorado upon a scale of one-fourth of an inch to a mile with one hundred feet contours) some of the preliminary steps have been taken along the coast regions of the country. The United States Coast and Geodetic Survey, which for many years has been carried on by men of unsurpassed attainments in their special departments of science, has laid the geodetic foundation for a topographical map of the country, so far as the work has been completed, along the two great oceans, the Gulf of Mexico, the lower Mississippi, the Hudson River and Lake Champlain, by a triangulation unsurpassed throughout the world for precision. Moreover, the precedent has been established by Congress, and is not likely to be departed from, of making special appropriations for extending this geodetic triangulation into States where the legislature will provide for geological and topographical surveys. Up to the present time, however, but little alacrity has been displayed on the part of individual States in availing themselves of this proposed co-operation. Special triangulations have only been made in New Hampshire, New Jersey, Pennsylvania, Kentucky, Tennessee and Wisconsin, by the Coast and Geodetic Survey.

In addition to the work of triangulation, an elaborate topographical survey of a narrow strip of land along and adjoining portions of the Atlantic coast has been made under the Coast Survey. The plane table method was employed, the field sheets being generally upon the scale of 1:10,000 or nearly that of the later maps of the British Ordnance Survey, namely, six inches to a mile. Upon these sheets contour lines are marked with vertical intervals, usually of twenty feet. The details of topography are otherwise shown with great minuteness. A series of sheets of this kind for the whole country would be of incalculable value for engineering and other purposes.

They would, however, still lack an important feature which gives great value to the Ordnance and some other European maps, namely, the delineation of property lines. The Coast Survey maps show fences and other lines of enclosure, but without regard to ownership. As all land surveyors know, the determination of the lines of actual ownership is a work involving peculiar difficulties, arising mainly from the imperfection and conflicting nature of the various kinds of evidence depended upon.

In Great Britain the Ordnance Surveyors are required to serve regular formal notices upon the land owners or their legal representatives, who are notified to be present at the time of the survey for the purpose of pointing out their lines and presenting the confirmatory evidence in their possession. By this means an official character is given to these boundary surveys which has the general subsequent effect of preventing much disastrous litigation which might otherwise arise. The addition of property lines, with adequate descriptions, constituting what are called "*cadastral maps*," not only serves to strengthen and perfect titles, but renders the maps useful for the equitable assessment of taxes, the adjustment of betterments for public

improvements, etc. The use of cadastral maps has already extended to Canada and to some of the larger American cities and towns.

Since, with its present organization and yearly appropriations, it would require many centuries to complete a survey of the entire country, in the style of the narrow strip above mentioned, even without the cadastral element, the work of the Coast and Geodetic Survey is at present limited to the completion of its series of admirable coast charts and the valuable scientific investigations connected therewith, and to the extension of the geodetic work across the continent from ocean to ocean. This grand triangulation, when completed, will afford an admirable basis for topographical maps made by such special organizations as the various needs of different sections may indicate.

The position of the Atlantic States gives them the advantage of the primary triangulation of the Coast Survey which already extends across the New England States to the Hudson River and Lake Champlain, and along the Blue Ridge and adjacent mountains of the Appalachian chain in Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia and Alabama. In addition to this general primary or geodetic triangulation the Coast Survey organization is well adapted to supply the secondary triangulation by which the geographical positions of many convenient points intermediate between the primary stations would be given for the convenience of the surveyors who would follow and work up the minute details of topography. Government co-operation to this extent with State surveys, topographical and geological, has already been established in the States of New Hampshire, Pennsylvania, and New Jersey, and will doubtless be called for in all the States successively as the advantages of topographical surveys become apparent to them.

In the meantime another government organization has undertaken the preparation of topographical maps and is prepared to co-operate with States in this work. The United States Geological Survey, originally organized to investigate the geological relations and resources of the national domain in the western territories, has been authorized to extend its researches over the entire country. The desirability of this is apparent when we consider that geological formations are independent of civil boundaries, and that their relations can be best ascertained by tracing them from State to State over the widest accessible areas.

The absence of good topographical maps presents at the outset a formidable difficulty in the way of geological investigation. Geology and topography are intimately related and, to a considerable extent, dependent upon each other. The officers of the Geological Survey are accordingly compelled to supply the deficiency by constructing maps for themselves as the work goes on. For this purpose a "Division of Geography" has been organized, with an accomplished and experienced chief, under whose direction skilled topographers are assigned to the sections where immediate geological work is intended.

The immediate benefits which will accrue from this undertaking even while in progress are so apparent that, having been fairly inaugurated, it is not likely to be abandoned in a progressive country like ours.

Its magnitude, however, assumes almost overwhelming proportions and the conditions under which it must be exercised are such as to call into exercise, judgment, skill and executive ability of a very high order. While the results must be reliable and accurate, rapidity of execution and economy in expenditure are also indispensable.

The first consideration which presents itself is that different parts of the country will need to be surveyed with different degrees of elaboration on account of the great variations in existing conditions. The older and more fertile portions of the country are already occupied by a dense population, much of which is concentrated in and about numerous large cities, towns and villages. An intricate network of roads and railways affords easy inter-communication between all parts of this inhabited region. On the other hand a large part of the country remains in the aboriginal condition of nearly unbroken solitude. Portions of this unsettled country are more or less susceptible of cultivation, or possess mineral or other industrial resources. These portions will eventually partake of the

general increase in the population of the country and its accompanying development of cities, towns, roads and railways. But there will always remain vast regions made up of wild mountain peaks, ridges, with steep rock-bestrewn slopes, precipitous cliffs, deep gorges, broad stretches of bare rock cut by impassable cañons and great tracts of arid and uninhabitable territory.

A high degree of precision in the rendering of minute details cannot be obtained in these wildernesses, except at a cost of labor greatly disproportionate to the uses which can be made of the maps. If the more general topographical features, only, are accurately shown, all useful purposes will be subserved, and the scale may be much smaller than when the details are elaborated with greater precision.

The scale adopted for maps which have been made under the U. S. Geological Survey, is one-fourth of an inch to a mile, and this will doubtless prove adequate for the record of such geological characteristics as can be ascertained for many years. In some of the mining districts, however, where the presence of rich metallic veins has caused a rapid settlement of the locality by eager searchers for wealth, the details of geological information developed by the miners are found to require special maps on a large scale for their proper display.

The question whether there shall be co-operation between State authorities and the U. S. Geological Survey in the construction of topographical maps has an important bearing in determining the scales which may be adopted by the Geological Survey, for the maps of those sections of the country included under State jurisdictions. Such a co-operation, for example has been proposed for the State of Massachusetts and is now under consideration by its legislature. The Geological Survey needs as a basis for its representation of the geological formations, a map upon which the outcrops and other indications may be accurately located by the geologist, both in their horizontal and vertical relations. The more numerous the recognizable points of reference, and the narrower the spaces between them, the greater will be the degree of precision with which he will be able to record his researches, and the more valuable will the record become. But the limited sum appropriated by Congress for the Geological Survey must be divided between the geological and the topographical work, which are to go on nearly simultaneously, the topographers keeping a little in advance of the geologists. The work of the "Division of Geography," though preceding it in the order of time, is subsidiary to the regular geological work of the survey, and is likely to receive a smaller share of the entire appropriation.

In the absence of co-operation by any State with the United States Geological Survey, in preparing the topographical map of that State, this limitation of means will, of course, appear in the final result.

In Massachusetts the scale of the existing State map is, as stated above, two-fifths of an inch to a mile. The U. S. Geological Survey has already done some preliminary work there, with a view of constructing a map with contour lines, on a scale of half an inch to a mile. It is evident, however, that this scale, about one-half that of the first British Ordnance Survey, would, like that, prove inadequate to serve the engineering and other purposes for which maps are needed by States and municipalities. In 1824 while the work of the Ordnance Survey was in progress in England, it was found necessary by the government to make a general property valuation of all Ireland. For this purpose the survey of that island was made on the scale of six inches to a mile, or 1:10,560 and the boundaries of farms, etc., were all carefully surveyed and delineated in addition to the other details of topography. When the survey of Ireland was finished in 1840 the maps were found so useful for other uses that the same scale was adopted for a re-survey of the kingdom, and, though the work was from time to time obstructed by the lack of adequate parliamentary appropriations, its real value has been so apparent that it has not been discontinued, and it must now be near completion.

The difference between the scale of the present official map of Massachusetts, two-fifths of an inch to a mile, and that of the larger Ordnance maps of Great Britain, six inches to a mile is, in linear dimensions, as one to fifteen; in area, as 1 to 225. That is, it would take 225 times as many sheets of the same size to show the whole of Massachusetts, upon

the scale of the Ordnance map, as upon Borden's map. The cost of adopting the Ordnance scale is evidently too great to be undertaken at present, and for the general map of the State, a publication scale of 1:50,000, or about one and a quarter inches to a mile is probably as large as would be required for most of the purposes for which it would be used, including preliminary investigations for railway locations, for water supply of cities, etc. This scale has been recommended by international scientific conventions in Europe as the most practical and convenient for general uses. A convenient size for single sheets would cover ten minutes of latitude and twenty minutes of longitude, making the size of the sheet, exclusive of margin, about fourteen and a half by twenty-one and a half inches. About sixty-five sheets of this size would be required to cover the whole State including a number of fractional sheets along the sea coast.

The expense of preparing maps on a sufficient scale to serve for cadastral and other municipal purposes should, under our system of independent municipal sovereignties, be borne by each municipality whenever its want becomes felt. A number of cities and towns in this and some of the adjacent States have already provided themselves with such maps, and it is probable that others might have them provided in connection with the proposed survey, by defraying the additional expense of increasing the scale, giving property lines, areas of lots, etc.

The cost of the general survey of the State, of which the above general outline has been given has been estimated by the Geological Survey at about $80,000 to be distributed over four years. Of this expense the Geological Survey proposes to defray one-half. It is not easy to ascertain in advance the exact cost, which will depend upon the minuteness of the details and the degree of precision with which they are represented.

Some of these details, for example, consist of the outlines of woodland, of pastures, the minute meanderings of streams, fences, stone-walls, buildings, etc.

Another element of variation in expense is the differences of level between adjacent contour lines. For the scale of 1:50,000 proposed, twenty-five feet might be adopted for the intervals between contours over the more level portions of the State, and fifty feet for those among the mountainous regions.

For comparison of the work proposed with the surveys of Europe, the following concise account of some of them has been taken from an interesting paper in the *North American Review* for July, 1875, on "Geographical Surveys," by Professor J. D. Whitney, who has given careful attention to this subject:

"Let us begin with Great Britain, which, including Ireland, has an area of nearly 111,000 square miles, and where the topographical survey has been going on since about 1784. The scientific work is partly performed by officers of the Royal Engineer Corps (382 military, including officers, and 1,446 civil assistants were on the Ordnance Survey staff in the year 1872), and it is officially known as the "Ordnance Survey." Its total cost from 1791 to the end of 1864, including the military pay of the men employed, was £2,991,624, and may be estimated up to the present time about £4,200,000. The scales adopted are numerous, and in case of some cities are as large as five and even ten feet to the mile. The principal published maps, however, are on two scales, one of six inches and the other of one inch to the mile (1:10,560 and 1:63,360). Of England, the map on the one-inch scale was begun in 1784 and finished in 1869; but the projection employed in it was defective, and it is in other respects not up to the present requirements of the country, hence it is now in process of working over and re-publication. Of the area surveyed on the six-inch scale, 24,877 square miles had been completed in England and Wales, and 27,829 in Scotland, up to the end of 1873, Ireland, on the same scale was entirely finished in 1845, and all the sheets, 205 in number, published without, and about half with, the hill-shading. Besides the maps on the six-inch and the one-inch scales, plans are furnished of any district as called for on the scale of 1:2,500 (about 25 inches to the mile), made by photo-zincography: but these are not necessarily engraved or published. The map of London is on a scale of 1:1,000, and is comprised in 821 sheets. The various publications of the Ordnance Survey are sold in single sheets as wanted at very

moderate prices; but so great as to their number, that the cost of a complete set, as far as published amounts to over £3,000. A great deal of work is prepared for the use of the government on very large scales, but it is chiefly the six-inch and one-inch maps which are of importance to the general public. At the present rate of progress it will require about ten years to complete the survey.

In Belgium the scale adopted is 1:20,000, the area of the country being about 10,000 square miles, 450 sheets will be required, of which 137 were published up to the end of 1873; the contour lines are drawn at distances of one meter, every fifth one being indicated by a heavier line; the sheets are lithographed and printed in colors, the rivers and lakes being in blue, the lettering and roads in black, the meadows and forests in different shades of green, the buildings in brick-red, and the gardens in carmine.

In Prussia, since 1849, new and more perfect methods have been introduced into the topographical surveys; the plane-table sheets are now published on a scale of 1:25,000, and with contour lines with distances of five, twelve and a half or twenty-five feet according to the nature of the country. The publication of the plane-table sheets was commenced in 1868, and in 1873 120 had been issued. There has also been, since 1841, a general map in process of publication, on a scale of 1:100,000, which will be comprised in some 400 sheets, of which nearly all are issued. These are engraved on copper and have the topography, or hill-shading indicated according to Lehman's system as modified by General Müffling.

In Baden, the new map was commenced in 1874, on a scale of 1:25,000, and with contour lines at ten meters distance. The work is mainly a revision and correction of older surveys and is expected to occupy six years at a cost of about 80,000 florins.

In Saxony, the original survey was commenced in 1780, and completed in 1806 on a scale of 1:12,000, the area of the kingdom being 5,600 square miles. A topographical map was issued in the years 1837–1860 in 22 sheets and on a scale of 1:57,600. A new map was determined on in 1860, and it was completed in ten years; there are two editions of this, one with the line-work only and the other with the hill-shading.

Having now shown what is doing in some of those European states which are, comparatively speaking, rich, densely inhabited, and with moderate areas of territory, let us turn to the consideration of some countries which have only a thinly scattered population and a large area. Russia, for instance, with its enormous territory, just about twice the size of that of the United States, Alaska included, has been for many years actively engaged in prosecuting geographical surveys. The map of Russia in Europe, embracing about 2,100,000 square miles has been under way since 1857, and will be embraced in about 700 sheets, of which 454 had been published in 1872. This is on a scale of 1:126,000. The military map of Poland is on the same scale and is embraced in 57 sheets, all of which are published. Special maps of the Caucasus have also been completed and, recently, a map of Central Asia.

Norway has an area of 123,300 square miles, and a population about that of Massachusetts; that is, our own State is eighteen times more densely populated than Norway. But this comparatively poor country has set itself on having a good topographical map on a scale of 1:100,000, and which will occupy over 200 sheets. Those which have already appeared have been highly praised for their execution by competent judges; they are printed in chromo-lithography, like those of Belgium.

Sweden also, very similar to Norway in respect to area and density of population, has her topographical maps on the same scale (1:100,000) and the work is already nearly half completed, the first sheet having been published in 1860.

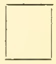
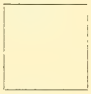
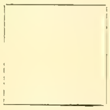
The following information in regard to the surveys of other European states, in addition to those enumerated by Professor Whitney, has been gathered from reliable sources. (See *Geographical Magazine*, Vol. IV., p. 125 *et. seq.*)

Saxony, in addition to the maps before mentioned, has undertaken a new survey on a scale of 1:25,000 to be comprised in 156 sheets, the elevations to be shown by contours, with crayon-shading to bring out the relief.

Bavaria, having in 1868 completed her map in 112 sheets on the scale of 1:50,000,

SCALES OF TOPOGRAPHICAL SURVEYS.

EXPLANATION.—Each square is drawn with sides of one-half mile on the scale designated, which is indicated both in the natural way by giving the proportion to nature without regard to any standard of measurement, and by "Inches to a Mile."

U. S. GEOLOGICAL SURVEY. (Maps of Western Territories.)		$\frac{1}{253440}$, or $\frac{1}{4}$ Inch=1 Mile.
MASSACHUSETTS. (Borden's Map, 1884.)		$\frac{1}{158400}$, or $\frac{2}{5}$ Inch=1 Mile.
HUNGARY.		$\frac{1}{144000}$,, or 0.44 Inch=1 Mile.
RUSSIA.		$\frac{1}{125720}$, or $\frac{1}{2}$ Inch=1 Mile.
PRUSSIA (General Map). NORWAY. SWEDEN. PORTUGAL.		$\frac{1}{100000}$, or 0.636 Inch=1 Mile.
FRANCE (General Map). U. S. COAST SURVEY, (Published Coast Charts.)		$\frac{1}{80000}$, or 0.792 Inch=1 Mile.
AUSTRIA (General Map).		$\frac{1}{75000}$, or 0.8448 Inch=1 Mile.
GREAT BRITAIN (First Ordnance Survey.)		$\frac{1}{63350}$, or 1 Inch=1 Mile.
NETHERLANDS. SWITZERLAND (Mountains). ITALY. BAVARIA. WURTEMBURG. SPAIN. Proposed Survey of Mass. (Public'n Scale).		$\frac{1}{50000}$, or 1.2672 Inch=1 Mile.
DENMARK.		$\frac{1}{40000}$, or 1.584 Inch=1 Mile.

Proposed Survey of Mass. (Field Sheets.)	$\frac{1}{30000}$ or 2.112 Inch.=1 Mile.
Prussia (Field Sheets) Austria " Bavaria " Italian States. Switzerland. Saxony. Baden.	$\frac{1}{25000}$ or 2.5344 Inch.=1 Mile.
Belgium. Italian States (Field Sheets). France (Department of Seine).	$\frac{1}{20000}$ or 3.168 Inch.=1 Mile.

Inner Square.

$\frac{1}{10560}$, or 6 Inch.=1 Mile.

Ordnance Survey of Great Britain.

Outer Square.

$\frac{1}{10000}$, or 6.336 Inch.=1 Mile.

U. S. Coast Survey. (Field Sheets.)

has a new edition in progress. Also publishes photo-lithographic copies of the original plane-table sheets, scale 1:25,000.

Wurtemburg has also a map on the scale of 1:50,000, of which a new edition is in progress.

Austria commenced in 1874 a new map comprising 715 sheets, scale 1:75,000, each sheet including 15′ of latitude and 30′ of longitude. The drawings for this map are transferred to copper and the engraved plate is produced by etching. 151 sheets had been published up to 1878. The survey scale is 1:25,000. This map must now be near completion. Hungary covers 198 sheets on a scale of 1:144,000. The environs of Vienna are shown in two maps on the scale of 1:12,500 and 1:25,000. Hills are shown by contours having intervals of ten meters, with crayon-shading, roads are printed in red, forests tinted in delicate green, and the outlines and lettering in black.

Switzerland has a fine large map beautifully engraved in hachure, but is preparing a new survey in 546 sheets, the scale of the cultivated districts being 1:25,000, while the barren mountain regions are shown on the scale of 1:50,000.

The Netherlands issues a new edition of her map on the scale of 1:50,000.

Denmark has a survey in progress, scale 1:40,000.

The great map of France is on the scale of 1:80,000 and is comprised in 267 sheets. Contour lines are printed in brown, and water in blue. Some of the departments are being published on the scale of 1:20,000.

Italy is being mapped on the scale of 1:50,000. The field sheets are on the scale of 1:25,000.

Spain, with a good general map by Coelho, has been engaged since 1858 on a new survey, scale 1:50,000. Each sheet covers 10′ of latitude and 20′ of longitude. The intervals between contours are 10 and 20 meters. Rather slow progress is being made.

Portugal commenced a map in 1856 on the scale of 1:100,000. The earlier published sheets showed the hills in hachures, but of late the contour system with intervals of 25 meters has been adopted.

The accompanying diagram is intended to show the proportions of the different scales which have been mentioned. Each square is drawn to the scale designated, with its sides half a mile in length.

A brief summary of the entire mode of procedure to be used in constructing the proposed topographical maps by the U. S. Geological Survey in Massachusetts will show the high degree of accuracy that may be expected from it.

The first operation, which has already been completed by the State Trigonometrical Survey and by the United States Coast and Geodetic Survey, was the primary triangulation of the entire State by which the positions of about one hundred points in different parts of the State were determined with the highest degree of precision attainable by human instruments and methods. This precision has been tested by measuring two base lines, hundreds of miles apart, and comparing the length of one, obtained by computation from the other along a series of intervening triangles, with its actual measured length. In this way the Coast and Geodetic Survey proved that the amount of possible error in their determinations of the relative positions of the intervening points, is limited to less than one two-hundred-and-fifty-thousandth part of the actual distances, or less than one foot in fifty miles.

The next step in the work is the secondary triangulation by which numerous points intermediate between the primary stations are located to serve as reference points for the subsequent survey of the topography in detail. It is advantageous to have as many as possible of these reference points and they should be well defined and conspicuous objects. Borden fixed the positions of some 350 secondary objects, consisting mostly of churches and other public buildings. But the forty years which have since elapsed have brought many changes. Many of the churches, etc., have been razed, burnt or removed and other points of reference have become obliterated.

The Coast and Geodetic Survey also located many secondary and tertiary points and made use of them in preparing the topographical sheets of the narrow strip along the coast, mentioned above. This strip is, however, wider than usual along parts of the Massachusetts coast. It includes the islands of Martha's Vineyard and Nantucket and nearly all of Cape Cod.

The area over which the topography is thus completed is about 800 square miles, which for the proposed co-operation scheme only needs revision for the purpose of adding town and city boundaries, new roads, railways, mill-ponds, etc., with some changes in the outlines of the coast near Cape Cod, caused by the inroads of the ocean waves.

The remaining area of the State, about 7,000 square miles, will need to have a great many secondary stations fixed by preliminary triangulation to prepare for the delineation of the topographical details. This secondary triangulation does not require the amount of refinement which is requisite for the geodetic or primary triangulation, upon which depends the precision of work hundreds of miles away, and the final determination of the form and size of the earth. Having the primary stations to work from, the precision obtainable, even with the ordinary instruments used by civil engineers, is quite sufficient for cartographical purposes, since it exceeds the capabilities of graphic delineation.

The plane table, an instrument which enables the surveyor to construct his map in the field by the graphic method, has been used by the Coast Survey from the commencement of its topographical work, and all its topographers are trained in its use. For cartographical purposes it has many advantages, as it dispenses with much of the work of ordinary surveying, the measurements of distances and angles, the keeping of field notes and subsequent plotting of the notes by protractor and scale. By this method after the trigonometrical points have been projected upon the field sheets, other points are marked by intersections of lines drawn by a ruler with an attached telescope, called an *alidade*, which being placed over the point occupied is directed toward any point to be located. When another known point is occupied and a second line drawn towards the desired point, the plane table being in both cases properly "*oriented*," that is, the direction between any pair of points upon it being made parallel to that of the corresponding pair upon the ground, the intersection of the two lines gives the position of the new point upon the map. Moreover, when the plane table is placed over an undetermined point from which three determined points are visible, its position can be ascertained and marked upon the map by a graphic solution of the three-point problem. In addition to these and other graphic methods of solving trigonometrical problems, the features of the ground in the immediate vicinity of the point occupied may be conveniently represented by the aid of stadia or telemeter rods carried by assistants over the ground from point to point. The distance of the rod from the plane table is seen by inspection in the telescope of the alidade and corresponds to the number of divisions, conspicuously painted upon the telemeter, which are intercepted between two horizontal hair lines in the telescope. Of course the direction to the point where the rod is held is given at once on the map by the ruler of the alidade.

The more numerous the points instrumentally determined, the more accurate should be the final result, as between these points, the lines of contours, streams, etc. must at last be sketched in by the aid of the eye which requires careful training for the proper estimation of the proper proportions in nature and for their reproduction in the sketch. Our philosopher-poet, Emerson, says "a work of art is an abstract or epitome of the world. It is the result or expression of nature in miniature."

The converse of this is also true, and topography, though based upon exact science, is entitled to rank among the fine arts. The most skillful topographer is he who is able to give the real expression which pervades the face of nature corresponding to that which is seen in the human countenance, an expression which is the revelation of the forces which have acted to produce it.

The geologist studies the active agents of natural forces, the ocean waves and tides, the winds, rains and running streams, and ponderous creeping glaciers; the slow action of gravity, incessantly carrying down the great basins of deposit which would otherwise gradually become filled up, and raising the places which are lightened by the robberies of the wearing waters, keeping up thereby an underground movement, which with the surface movement, constitutes a complete *circulation of materials*; and the occasionally sudden action of gravity, when the

strained sheets of rock finally give way, and move to new levels of temporary equilibrium with accompanying earthquakes and lava flows. He sees the sculpturing effects of the super-terranean agents which are continually carving the face of the earth into forms which reveal its past history even from those inconceivably remote ages when its living inhabitants, its plants and animals, were strangely different from those of the present day.

These studies enable him to detect incongruities in the work of an unskilled topographer whose representations of the surface conflict with the true character of the underlying rocks carrying the characteristic marks of the subterranean agents which have bent and torn them, while lifting them to be shaped into grand and beautiful contours of the ever varying landscape.

The use of the plane table may in some respects be compared to the work of the artist who plants his easel in the field where he can compare his picture with nature as it progresses. It has been adopted by the U. S. Geological Survey, whose topographers find it especially well adapted for mountain topography. The accuracy of the method is only limited by the conditions of graphic representation, and if the proposed survey of Massachusetts is made, this will be the method employed.

If all the sheets of the map on the proposed scale of 1:50,000 are joined together when completed to make one continuous map it will extend about twenty feet from east to west. Such a sheet would be too unwieldy for ordinary uses, most of which could be conveniently made with the separate sheets. It would be easy, however, to join any required number together, making continuous maps of entire counties, of drainage areas and of preliminary surveys for railways, for water supply and for sewerage of cities, etc.

For schools and academies, a small number of sheets covering the surrounding region, joined together and hung upon the school-room wall, would enable pupils to study the physical geography of their own immediate neighborhood, and to cultivate habits of exactness in observation and comparison.

Plaster models of parts or the whole of the State could be made for museums, colleges, etc., with little difficulty, showing in miniature all the inequalities of the surface in their true proportions.

The exact areas, relative positions and differences in heights, of drainage basins, lakes, ponds, swamps and meadows could be found, for sanitary and other purposes by inspection of the maps.

To enumerate, indeed, all the useful purposes of such a series of accurate maps would be difficult if not impossible.

The question now presented to the legislature of Massachusetts is whether the State, by co-operation with a trained organization of high character, will secure a survey of this nature at less than half the cost which would be incurred in a separate undertaking.

On the other hand in case the State declines to co-operate, the Geographical Division of the U. S. Geological Survey expects to prepare a map at a cost of about $20,000. The result will be a map having a greater scientific value than the present map, but falling far short of fulfilling the engineering and other State purposes which are attainable by the proposed plan of co-operation.

Is it not to be feared that this course would have the effect of postponing the more elaborate survey until the false economy of the delay should have become evident, even to the most unappreciative minds by repeated wasteful expenditures that might have been avoided by improving the present opportunity?

Viewed with regard to the welfare of the whole country it would seem that a scheme of national co-operation such as has been outlined above, is worthy of the careful consideration of each of the several commonwealths. The amount of detail for each State and the consequent cost of the work having been adjusted to its special needs, the conduct of the survey under a skilled national organization would be likely to accomplish far more satisfactory results than if State surveys were independently organized.

THE great tower of Norwich Cathedral is in a state which is causing anxiety, and, like the Peterborough Cathedral, may have to undergo important and expensive operations. The wall of the tower near the top is weakened by the introduction of a passage and open arcade, and the weight of the spire above is causing settlements in that part. It may, however, be possible to put in the saving stitch.

ON A PRACTICAL SOLUTION OF THE PERFECT SCREW PROBLEM.*

By Prof. WILLIAM A. ROGERS.

From "English Mechanic and World of Science."

Prof. Rogers said that at the outset it was essential that the term "perfect screw" should be defined. Perfect is a relative term. A piece of mechanism may be termed perfect when it meets all the requirements of the purpose for which it was constructed. After describing the errors to which screws are subject as being an error in the total length, the pitch of the screw for even revolutions not being uniform, and the fact that there may be a gradual increase of pitch up to a certain point, and then a diminution until the amount of decrease is equal to the previous amount of increase, he detailed the most important failures to make satisfactorily perfect screws, and continued:—An order was received from Prof. Wm. A. Anthony for the construction of a dividing engine for the Physical Department of Cornell University. Upon accepting the order, a shop was fitted up in Boston with tools of the best quality, chiefly from the establishment of Pratt and Whitney, and Mr. Ballou undertook the construction of the engine, mainly from his own designs, and of the screw which is its essential part. The completed machine was shipped in just 35 weeks after the actual commencement of the work; and the screw, which will be presently discussed, was cut and ground in 27 hours from the time the first tracing of a thread was made. It was at that time practically perfect for about 20 inches, and nearly as perfect as it afterwards became by the process of grinding adopted. Notwithstanding the fact that the work was done upon a common lathe in which the errors of the leading screw were enormously large, the result showed that the method employed was based upon correct mechanical principles, and was entirely feasible.

This method can be described in a very few words.

Let the reader hold clearly in mind the following. There are:

1. an ordinary lathe, the ways of which have been made as nearly straight as possible.

2. A shaft between dead centers which maintains a cylindrical form during every revolution and every part of a revolution.

3. A microscope provided with Tolles' opaque illuminator for viewing opaque objects, attached to the carriage moved by the leading screw of the lathe.

4. A graduated bar mounted independently of the carriage, with subdivisions which are multiples of single threads of the leading screw.

5. A slide moving parallel with the leading screw, by means of a very short and firmly mounted micrometer screw of comparatively large diameter and attached firmly to the carriage. The toolpost is secured firmly to the secondary slide.

6. A mechanical means of determining when the leading screw has made a complete revolution.

The method of proceeding was as follows:—The graduated bar having been leveled up and set parallel to the axis of the screw to be cut, the micrometer of the microscope was set upon the initial line. The lathe was then started with the leading screw "in feed." After the screw had made, for example, nearly ten revolutions, the lathe was stopped and the remainder of the even revolution was completed by hand manipulation. The deviation of the micrometer line from the corresponding graduation upon the bar was then measured in terms on the screw head of the secondary micrometer screw. In this way the errors of the leading screw with respect to the graduations of the standard bar were determined and written down upon a strip of paper pasted to the vertical face of the bar. The carriage was then started again with the cutting tool in operation, and by means of a rough pointer, the micrometer screw

* A paper read at a recent meeting of the American Society of Mechanical Engineers.

working the secondary slide was fed either forward or backward, in accordance with the corrections before determined. Hence, when the even revolution was completed, it would be found that the line of the bar would be nearly under the cross wire of the microscope. This operation was kept up until the screw was finished.

At the completion of the operation of cutting, it was found:

First.—That the total length of the screw corresponded nearly with the length of the line standard from which it was cut,

Second.—That there were at many points minute irregularities of pitch, due to the fact that the application of the corrections intermediate between the main divisions had not been exactly made.

Third.—That the crucial test of the removal of these irregularities by grinding with a brass nut was a complete success. As had been predicted, they were for the most part removed after an hour's grinding.

The method of testing was as follows: Two half nuts with projecting arms resting upon the /‾‾‾‾‾\ shaped way were first placed at a fixed interval apart. A microscope was mounted on one nut and coincidence was made between the micrometer wire of the microscope and a line drawn upon the upper surface of the other nut. It is obvious that if the relation between the different threads of the screw remained constant, the line under the microscope would remain constant. This constancy under half-inch objective was maintained for about 20 inches. Then the nuts began to separate, and the separation continued until the maximum deviation amounted to about $\frac{1}{5000}$ of an inch; but near the end the nuts came back to their first relation.

In order to eliminate these residual errors, together with what errors might remain which were a function of one revolution of the screw, the following method was employed. The grinding nut was made in halves, in such a manner that a constant relation was maintained between the halves, both in their normal and in reversed positions. By grinding the screw, first with halves of the nut in their normal relation and then in reversed relations, the tendency was to continually work out the periodic errors of the screw, with the exception of minute errors which were transferred from the screw to the nut during the operation of grinding.

In order that the nut might grind without disturbing the general relation between the threads, a cast-iron cylinder with a center at the bottom was filled with the best sperm oil, and the screw was mounted vertically upon this center. At first two broad fans were attached to the nut in the hope that the resistance of the oil, which in this case would be symmetrical with respect to the axis of the screw, would be sufficient to drive the nut upon the screw. As this movement was found to be too slow, a guiding rod was used.

The grinding process was continued for three weeks, and the results obtained confirmed previous experience. At the end of the first week the maximum error of $\frac{1}{5000}$ of an inch had been reduced about one half, but it was found that small errors had been introduced in the mean time at other points, through a slight transfer of the errors of the screw to the nut itself and from thence back to the screw. Near the end of the second week the screw was clearly less perfect as a whole than at the commencement of the operation of grinding. Mr. Ballou then recut the nut, making its diameter a little less than that of the screw. Within a few hours thereafter a decided improvement was observed. A new nut was made at the end of the second week having its diameter still a little less than before. During the third week the gain consisted for the most part in eliminating the errors which had been introduced during the second week. Throughout the entire operation of grinding, reversals were made every hour both of the halves of the nut and of the screw upon its centers.

Prof. Sweet, in the course of discussion, said that having obtained a practically perfect screw, there remained the difficulty of using it so that it should remain perfect. In using a comparatively short nut on a long screw, the screw under the ordinary conditions of use was unequally worn at different places in its length, the result being that the originally accurate screw soon became full of inaccuracies. Were it possible to use a nut of a length equal to that of the screw the accuracy of the latter might be maintained. Imag-

ine a long and nearly accurate straight edge, but with small local inaccuracies along its length, and then trying to remove these inaccuracies by grinding with a short and perfectly accurate straight edge, and you have a fair idea of the conditions existing in the use of a short nut and a long screw. The accurate straight edge must be as long as the one it is used to correct. He had often thought that, in the lead screw of a lathe for instance, by removing some of the threads on the parts of the screw that were used the least the tendency would be to a better preservation of the accuracy of the screw, but as in many other things, he had never had the courage of his convictions in a sufficient degree to do what he thought was right.

ENGINEERING NOTES.

The report of the directors of the Panama Canal Company on the present condition of the works states that the number of men employed in May, 1884, was over 19,000. It is calculated that the excavations amount to 110,000,000 cubic meters, in addition to 10,000,000 cubic meters of earthworks in altering the course of the Chagres. Up to the end of April, 1884, the total amount of work done is represented by 5,243,302 cubic meters of earth removed. Until January 1st, 1884, however, the real work of cutting the canal had scarcely fairly begun, and of the total of 5,243,302 cubic meters of earth removed, nearly half, that is to say, 2,482,768 cubic meters have been removed in the first four months of the present year. In the total of 120,000,000 cubic meters of ground to be excavated, 40,000,000 will be taken away by means of dredgers. The projector says there can be no doubt of the canal being open for navigation before the close of 1888.

The proposal to construct a ship canal across Ireland is again to the fore. The Dublin *Freeman's Journal* has published particulars of the project for constructing a ship canal across Ireland, which it assures its readers is a reality, and has been warmly espoused by influential people in England. "Elaborate plans and surveys have been made at considerable expense, and have been submitted by Captain Eads, the American engineer. The proposed canal would be 127 miles in length, and would contain thirty locks. For ships of 1,500 tons the cost would be £8,000,000; for ships of 2,500 tons £12,000,000; and for ships of 5,000 tons and upwards £20,000,000. If built on this scale the canal would be 200ft. wide on the surface and 100ft. at the bottom. The passage through the canal would be effected by a system of towage, and it is estimated that the passage of a ship from Galway Bay to Kingstown would occupy between twenty-four and thirty-six hours. An alternative scheme of a ship railway, on which the ships would be carried in cradles, which could be constructed for £10,000,000, is proposed, by which the duration of the passage through the island would be reduced to twelve hours An immense aqueduct would have to be constructed to carry the canal over the Shannon at Banogue. It would be over three miles in length, and would be one of the most difficult and costly works in connection with the undertaking."

The producers of petroleum on the western shore of the Caspian Sea have been contemplating seriously the laying a pipe line entirely across Persia to the Persian Gulf. If this were done they say that they would have the Asiatic market to themselves; which is not so certain, however, because there would be no traffic to the Persian Gulf port for vessels taking petroleum to India, China, &c., from it. A pipe line would have to be something more than 700 miles long to reach the coast, and as it would for a long distance pass through a territory of savage Kurds and other nomadic tribes, it is feared that it could not easily be kept in operation.

The preparatory measures for the junction of the sea of Aral with the Caspian Sea have reached a further stage by the return to St. Petersburg of the Russian expedition which has been surveying the route. The Russian Government was so convinced of the important nature of the proposed water-way that General Gluchowsky, the originator of the idea, was sent at a cost of nearly £100,000 with a corps of experts and engineers to make the necessary investigations. The results of this step have not been made public, on the ground of their being under examination by a commission. It is, however, concluded in some quarters that the silence of the official press indicates the non-fulfillment of the original expectations.

Bridges and structional ironwork have been in fair demand during the past six months, and Messrs. Matheson and Grant in their "Engineering Trades' Report" say: "Prices have fallen only in proportion to the slightly lower cost of iron. The ironwork required at home has been mainly for the widening of railways and the extension of existing stations. The application of machinery to the manufacture of iron structures has been much improved during the last few years; portable as well as fixed hydraulic riveters are now almost universally used, and multiple drills form a more important part of factory equipment than formerly. The English system of riveted connections is still preferred to the American plan of links or 'eye bars' with pin connections, and though bridges according to the latter method come into competition with English bridges in South America, and have even been imported into the Australian Colonies, the English riveted bridges are preferred where stability and permanence are valued. Steel is becoming more used as its price approaches that of iron. Besides the Forth Bridge, which will require about 10,000 tons of steel per annum for the next four years, steel bridges over the Hoogley and the Indus are being made for the In-

dian railways, and will do much to render engineers and manufacturers acquainted with its use. In London, the railway bridge over the Thames at Blackfriars is being doubled, the South-Eastern Railway bridge at Charing-cross is to be widened, Hammersmith Suspension Bridge is to be strengthened, and a new iron bridge is to be built at Battersea. The long proposed bridge across the Thames by the Tower will probably soon be built."

IRON AND STEEL NOTES.

Bessemer Steel for Engineers' Tools.—How nearly Bessemer steel can be brought to crucible in its usefulness for tools is a matter than which there are few more important to the machinery engineer. The advance of the Bessemer metal in this respect means to him a considerable saving of money. It may not, perhaps, be generally known that the Barrow Hematite Steel Company is doing a good deal in the production of Bessemer steel for uses hitherto served by crucible steel. In addition to its usual out-turn of heavy steel, in the form of rails, blooms, tires, &c., the company is producing upwards of 1,000 tons per week of special steel, which is being worked up in various parts of the kingdom into all the following forms:—Roll-turning and lathe-turning tools, chisels, files, shear blades, rail drills, rail punches, shear steel for welding to iron, miners' drills and tools, picks, shovels, hand hammers, roller bar and cotton spindles, locomotive engine, wagon, carriage, coach, and furniture springs, bolts, nuts, rivets, pit-ropes, telegraph, crinoline, and corset wire, umbrella frames, wire for musical instruments, and the like. Nor has cutlery itself been found too hard a test; for this special steel has been made even into razors with decidedly good results. Touching the extent to which the articles answer, it may be mentioned that a 1-inch pit chain, made from a soft sample of this special Bessemer make, withstood a breaking load of 35.63 tons; elongation, 6 inches or 18 inches. The welding had been done by a smith not accustomed to chain work. This is very encouraging to machinery engineers, with whom Bessemer steels are gaining favor to the supplanting of cheap cast steels.

Observations on Hardening.—Too many of the so-called steel articles sold in the market are either made from steel incapable of being hardened, or are not hardened at all. Good cast steel can be hardened and tempered so as to receive and retain an edge. This is not required of table cutlery generally—only of the carving knife—but it is required of the hand saw and the buck saw, of the spade and the manure fork, of the scissors and the pocket knife. Saw blades (so far as the writer has tried them) are not hardened; they will not retain "set" nor hold edge. They are gummed as they come from the rolls and the slitting machine, with no pretence at hardening or tempering. But they are stamped "cast steel," and that probably satisfies the public; but there are mechanics who would pay something extra to get good hardened and tempered saw blades, even at a much higher cost than that of the soft plates, the teeth of which can be bent by thumb and finger, and the set of which is removed by sawing through an inch thick spruce board. A spade is only an enlarged chisel; it should be capable of retaining an edge sufficient to cut through tough turf and dead grass. But most of the "cast steel" spades in the market can be sharpened as readily by drawing the edge cold under the hammer as by the grindstone. The edge never breaks, but batters and bends. The trouble with almost all the cast steel tools put ready made on the market is that they have never been hardened. Cast steel unhardened is as soft as wrought iron uncasehardened. A cast steel hammer became so indented on its face by driving nails during one season in jobbing that it had to be reground and polished. Yet the hammer was of steel capable of being hardened, as was proved by its being subsequently hardened and drawn to temper. It is quite possible that the reason why many of these articles prove to be soft is, not that the material is not good, but that they have never been hardened. Brightened steel that has not received a hardening may respond in after-heating to several of the tempering colors; and this is probably one reason why common steel articles are not thoroughly hardened. It is not uncommon to see a forger or temperer heat a piece of cast steel to a very low red—a red that shows only in the shadow—and then brighten and draw the temper to color, when after-trial proved that the steel had never been hardened. Indeed, the dull red that some smiths use for hardening such tools as cold chisels and other low-grade tools is that at which a red annealing may take place, the piece being heated to a dull red and plunged into water. The first requisite in making a cast steel tool into a working tool is to harden it. After its hardness is proved then it may be tempered to the condition required. There is no intermediate process of properly tempering between absolute hardening and subsequent drawing.

RAILWAY NOTES.

The whole extent—75 miles—of the Coude d'Eu Railway, in the Province of Parahyba, Brazil, constructed by Messrs. Wilson, Sons & Co., was successfully opened for traffic on 4th inst., this being before contract time.

It is now some twelve years ago that Messrs. Merryweather & Sons, of London, constructed their first steam tramway engine for the late Mr. Grantham. Since the failures of that time the economy and practical value of steam on tramways have been gradually proved in several parts of the world. The measure of success now obtained may be gathered from the fact that Messrs. Merryweather have received an order for fifteen of their tramway locomotives for use on the North London tramways. This tramway company has waited until experience has improved tramway engines sufficiently to add economy to the advantage they offer as to haulage power.

About 94 per cent. of the double mileage of the railways in England and Wales is now worked on the absolute block system, and the greater portion of the single lines is under the same control, in addition to the train-staff system. In Scotland, the double mileage worked by the absolute block is 90 per cent. of the whole, and in Ireland, 22 per cent.

The active interest taken by the Austrian Government in the construction of railways in Bosnia and the Herzegovina is being further illustrated by the proposal for a line from Metkovic to Mostar, following the right bank of the Narenta, and designed to facilitate commerce while also serving useful strategical purposes. Metkovic is at present a point of junction between the steamboat service on the Narenta and the land transports. After the regulation of the stream it is expected that large vessels can reach this point. There are important coal deposits at Mostar. The total length of the line is 26½ miles, and the difference in altitude between the terminal points about 200 feet. The gauge is fixed at 29.92 inches so as to correspond with the Brood-Serajero line. The permanent way will consist of steel rails 3.54 inches in height, and weighing about 34 lbs. per running yard, the maximum gradient not exceeding 1 in 300. There is a tunnel about 150 yards long, and various cuttings through rocky ground, &c. The three stations are principally intended for supplying water to the engines, as the country is thinly populated. The line is estimated to cost £170,000. It is in view to prolong the line to Serajevo, and a branch from Metkovic to Ragusa is also spoken of by the *Deutsche Bauzeitung*.

Some idea may be formed of the traffic on English railways from the following facts: —Through Farringdon Street Junction of the Metropolitan Railway 1,800 trains pass in twenty-three hours every day. There are four lines of rails, used by the Metropolitan, Great Northern, Midland, London, Chatham, and Dover, and Metropolitan Extension Companies. Through Watford Junction, on the London and North-Western Railway, 233 trains pass every day. This gives something like one in every four minutes of the twenty-four hours. At Cannon Street station, on the South-Eastern line, the number of trains using the station is 750 in one day. Through Clapham Junction the London and South-Western Railway had, in the year 1877, on an ordinary week-day, 656 trains, while on the Derby Day of 1876 no less than 1,023 trains passed through this junction. The number is now over 1,000. The total number of passengers conveyed in 1883, exclusive of season-ticket holders, was—first-class, 36,387,177; second-class, 66,096,784; third-class, 581,233,-476; total, 683,718,137; and season-ticket-holders, 180,000,000; total 863,718,137. Of minerals there were conveyed 189,485,612 tons; of general merchandise, 76,897,356 tons; number of miles run by passenger trains, 139,545,464; number of miles run by goods and mineral trains, 129,351,774; total miles run, 268,897,-236; miles of railways, 18,668; number of persons employed, 367,660.

The American Consul, Mr. Lyell T. Adams, at Geneva, writing on the subject of international railway communication, states that any account of the commercial position of Switzerland at present would be incomplete without some reference to the great change impending on the completion of the new lines of international communication, whose effect will be to make her a commercial, as she already is the geographical and hydrographical, center of the Continent. Nothing has isolated her, hitherto, but the altitude above the sea level, now overcome by the Brenner Railway, and the tunnels of the Mont Cenis, the St. Gothard, and the Arlberg recently opened. By these routes the extremities of Europe are brought into direct relations, the meeting point of all lying upon Swiss territory, with the exception of the Mont Cenis. This line crosses Upper Savoy, which, by the treaty of 1815 forms part of the Swiss neutral territory, to be occupied in war by the armies of the Confederation. One of its main feeders is the West Swiss Railway, from Berne to Geneva, and much of its traffic is likely to be diverted by the projected tunnel under the Simplon. What effect, adds Mr. Adams, this reconstruction of the European railway system will have on the fortunes of Switzerland, it is as yet too early to conjecture.

The construction of the Corinth Canal seems to have tended to increased activity in railway construction in Greece. A railway is being constructed in the Peleponnesus, starting from the Pyræus, which is the port of Athens. The station at Athens is about 1,500 feet in length and 130 feet in width, being near the Academy of Plato. The Kepissos is crossed by a bridge 90 feet in length, and the railway then traverses the north-western plain of Athens to Kameteron, following in a northerly direction the base of the Parnes mountain, subsequently penetrating through the narrow pass of Phylæ, and proceeding through the villages of Charia to Eleusis. The further portion of the railway from Eleusis to Megara was expected to be opened about the present time. The portion of the line from Megara to the Isthmus of Corinth presents the difficulty of a track overhanging the sea at a height of about 190 feet for a distance of nearly six miles, this romantic locality being known as the Scirronic Rocks. The completion of this portion of the line will hardly be possible before a late period of the Autumn. At Corinth the line divides the southern portion terminating at the cities of Argos and Nauplia. The western line follows the coast of the Gulf of Corinth, and goes through Ægium—Vostizza—to Patras. From that point it extends along the west coast of the Peloponnesus through Achaia, Gastuni, and Kalakolon to Pyrgos, in the vicinity of Olympia. The whole district traversed by the railway is thickly populated and in a good state of cultivation, the gain to local commerce being enhanced by the fact that there are scarcely any practicable harbors at that part of the coast.

The Lartigue Balance Railway.—A correspondent writes to the *Times:* Already a railway exists in Africa, working several miles, for the conveyance of the alfa plant

paper, which may possibly prove of good service in Egypt. This is the elevated single-rail system invented by M. Lartigue. It is said to be much cheaper in material, in working, and in the rapidity with which it is constructed than any other system. Although, as an agricultural railway, specimens had been exhibited and had gained medals at the exhibitions of Amiens and Amsterdam last year, the railway was first shown with electricity as the motor at the Palais de l'Industrie this spring. At the time I gave particular attention to the subject from an agricultural point of view, and obtained from the inventor himself much information concerning it. In due time it was seen in working order in the exhibition, and became quite a center of attraction, being visited by the president and many of the official notabilities. Messrs. Siemens had supplied, at eight days' notice, a very effective electrical motor, which, attached to light cars running on grooved wheels over a single bar of iron suspended about three feet from the ground, drew along goods and passengers in a very satisfactory manner. So light was it that an American general with me, who had put 250,000 men in the field, pulled along with his simple strength about fifteen cars, with the observation, "These trucks are a going concern." The sections of the rail are wonderfully light, the rail, bar, and standards weighing only about 65 lbs., and the cars for goods 75 lbs. A couple of workmen can set up several hundred yards of the line in a single day. Curves are made by simply bending the rail bar, and a few plain contrivances are applied which meet all the ordinary railway transit exigencies that occur. It is reckoned that the haulage power necessary to move the load on this system is 30 per cent. less than is required upon ordinary double rails. Riders of bicycles will readily understand this. The rail is, in fact, regarded as the backbone of an animal, and the burden is balanced or distributed on either side, hanging baskets or frameworks carrying variously shaped vessels forming cars which run on the center wheels. The center of gravity, being below the point of suspension, is not readily disturbed, so that the difference of half a hundredweight on either side only gives a slight "list" to the load without increasing the friction. Trusses of straw, baskets full of produce, vessels for oil, wine, &c., and frameworks for minerals were shown in various cars, and a passenger car to carry four or six persons was exhibited. This display was at the end of February. On returning to London with many detailed plans and illustrations of the system, I made a point of showing them in various quarters, among others, to the chief engineer at the General Post Office, and to scientific and agricultural friends, some of whom referred to the principle of the saddle-back or balance railway as being old. However, the detailed designs, iron standards, and models of carriages were recognized as novel and practical, while the electrical locomotive was undoubtedly new. Patents, in fact, have been obtained in France, England, America, and other countries. Such being the position, I was not astonished on revisiting France last week to find Lartigue's railway, with its single bar, occupying space at most of the Concours Regionaux. I saw it at Orleans this week attracting notice; and at the Rouen Exhibition, just about to commence, carriages for passengers on a large scale will be shown such as I have this afternoon examined at the foundry at Grenelle. The system is under the consideration of the French Government as one especially suitable for military purposes, forming a flying force from its portability. Along the iron standard, 3 feet or 4½ feet high, runs an iron bar, in which is enclosed and protected a telegraphic wire. Probably soon our own Government will duly consider this new system for military purposes, telegraphic and parcel communication. Our first Commissioner of Works, Mr. Shaw-Lefevre, has already evinced an interest in this French invention, and certainly it is time the system should receive scientific notice on our side of the Channel, which it cannot fail to do if you can afford notice of it in the *Times*. For warehouses, farms, contractors' works, mines, &c., the cost of this system is put at about 4s. 6d. a yard, and carriages of various forms are offered at from 24s. to 48s. each. The estimate given to a mining company in Ireland which has made enquiries for the construction of over two miles of line, to carry 200 tons in ten hours, is, inclusive of thirty carriages, only £1,350—a cost much below that of the miniature railway, running on two rails. The electric locomotive machine of Messrs. Siemens is divided into two parts, disposed and balanced on either side of the rail, following thus the general principle of the system. The motor is a dynamo-electric machine, with the current continued in circuit in connection with a fixed generating machine, and is so contrived that the oscillations of transit do not break the contact. The algebraic formulas and technical descriptions, in which engineers revel when forming comparisons of one system with another, may here be omitted, with the remark that, as French experts have worked out their sum, the results in favor of a railway running on a single bar are such as to commend it to the English public for practical consideration.

ORDNANCE AND NAVAL.

THE SEA-CELL AS A POSSIBLE SOURCE OF DANGER IN TORPEDO-EXPERIMENTS. By H. MOORS.

In considering the cause of a fatal accident, due to the explosion of a torpedo in an experiment conducted on board H.M.S. "Cerberus," the author was led to the conclusion that though in this case it was "not proven," still the electrical action set up between the zinc plate of the torpedo case serving as earth for the firing-current, acting as one pole of a battery when immersed in the sea, and the iron hull of a ship with which the firing-line could accidentally make contact, acting as the other pole, might in certain cases be sufficient to ignite the fuse. A battery thus formed would have no resistance and an electromotive force of about 0.514 to 0.564 volt; the platinum fuse ordinarily adopted has, according to the table given in the "Chatham Instructions in Military Engineering," a resistance of 0.325 ohm cold,

and 0.74 ohm at the fusing-point, the current sufficient to fire a charge being 0.75 ampere; a more sensitive detonator has a resistance of about three times the former, and requires only 0.32 ampere; the conducting wire used in the experiment was such as to give 126.8 yards to one ohm. From these data it results that the total resistance in circuit for firing the ordinary fuse with such a sea-cell would be 0.752 ohm, and allowing for the increase of the fuse's resistance with temperature, it would certainly explode with $44\frac{1}{2}$ yards of such a conductor in its circuit; and, owing to the uncertainty of the data adopted, a far greater margin of safety would be required. Experiments to test this theory were carried out by Messrs. G. S. Caldwell and G. Smibert, of the Post and Telegraph Department (the former was the first to propose the above theoretical deduction as the cause of the accident), and though unpublished, their results were placed at the author's disposal. The experiments were made on board H.M.S. "Malwa;" a zinc plate, 7 x 3 feet, was lowered clear of the hull, and a small portion of the rail well cleaned, with which the conductor was put in contact, by this means eight fuses of the regulation pattern were exploded through lengths of wire varying from 10 to 41 yards (175 yards of this conductor had a resistance of 1 ohm). An exposed surface of copper in connection with the iron, as was supposed to be the case on the "Malwa," would give a higher electromotive force than iron alone. The conclusions point convincingly to the possibility of accidental ignition from such a cause, and the necessity for due precautionary measures to prevent any such accidental contact in all torpedo experiments.—*Abstracts of Association of Civil Engineers.*

BOOK NOTICES.

Publications Received.

From Mr. James Forrest, Secretary of the Institution of Civil Engineers, we have received the following papers:

Emery Wheels and Emery Wheel Machinery. By Walter Osmond Rooper.

The Storage and Shipment of Grain. By Woodford Pilkington, M. Inst. C.E.

Experiments on Transmission of Heat. By Gustav Adolph Hageman.

The Basic Open-Hearth Steel Process. By Thomas Gillott, M. Inst. C.E.

The New York, West Shore and Buffalo Railway. By Peter Chalmers Cowan.

The Comparative Value of Labor in Different Countries. By Charles Ormsby Burge, M. Inst. C.E.

Stadia Surveying. By Arthur Winslow. Van Nostrand's Science Series, No. 77. New York: D. Van Nostrand. Price 50 cents.

Since good authorities have determined that with proper instruments the stadia method of measuring distances is as reliable as average chaining there has been manifested a strong disposition to adopt the method in quarters where it was heretofore unknown.

The inquiry for a suitable guide to the method had become quite a brisk demand before Mr. Winslow's essay was printed in the pages of Van Nostrand's Magazine.

The formulas and tables are such as are employed on the Geological Survey of Pennsylvania, and they form a part of the official report.

It is rare that so complete a treatise on the theory and practice of a method in surveying is found in so small a volume.

Besides the stadia tables the book is furnished with a table of logarithmic sines and tangents to four places of decimals.

Recherches sur L'Electricite. Par Gaston Plante. Paris: Revue la Lumiere Electrique. Price $3.50.

The importance which secondary batteries and accumulators have of late assumed has invested with a new interest the labors of M. Planté.

The treatise before us is divided into six parts. The first treats of accumulation and transformation of electric energy by aid of secondary currents. The second part treats of applications. The third part contains "Effects of Currents of High Tension." The fourth part, "Analogies between the Effects of High Tension and some Natural Phenomena." In the fifth part is described the Rheostatic Machine. The sixth part discusses the analogies between electric phenomena and some purely mechanical effects.

The book is beautifully printed and illustrated.

A Treatise on Earthy and other Minerals and Mining. By D. C. Davies, F. G. S. London: Crosby, Lockwood & Co. Price $5.00.

This book is devoted to an account of the more important minerals, their properties, localities and mining. The so-called useful and the precious or noble metals—in short, all those which are commonly used in the metallic state—have been discussed by the author in a previous treatise on "Metalliferous Minerals and Mining."

The minerals to which considerable space is given are, first, silica, and the chief combinations of alumina, magnesia and lime. Then in order come salt, sodium nitrate, borax, baryta and gypsum. Phosphate of lime is discussed through four chapters. Three chapters are given to carbon and one to sulphur.

What the author calls metallic minerals are represented by arsenic, cobalt, molybdeseum, antimony and manganese.

The illustrations are numerous, but rather poor, and as the above schedule indicates, the work is manifestly incomplete.

Forests and Forestry of Northern Russia. By John Croumbie Brown, LL. D. London: Simpkin, Marshall & Co.

In this, Dr. Brown has contributed another addition to his long list of treatises on Forestry. In this essay, as in the one immediately preceding it, there is to be found a large fund of information regarding the physical geography of the area described.

Part I. is devoted to a general description of

the forest lands, embracing besides the northern portion of Russia proper, Lapland, Nova Zembla, and regions still beyond.

Part II. deals with Forest Exploitation, and relates to all the Forest Industries, including the manufacture of tar, turpentine and vinegar.

Part III. gives briefly an account of the Topography, Fauna, Flora and climate of the region —in short is a concise treatise on Physical Geography of Northern Russia.

Memorial of Alexander Lyman Holley, C. E., LL. D. New York: American Institute of Mining Engineers.

The reader will find in this memorial a skillfully-arranged summary of the literary and practical works of Mr. Holley. The book is pleasant reading, not alone from the fact that much of it is the composition of a near friend who wields a graceful pen, but also from the fact that the most earnest praise in the volume is from the foremost men in Mr. Holley's profession; men who were the best possible judges of his worth and his work, and who regard with evident pride the record of their compatriot.

At the memorial session of the American Institute of Mining Engineers, held a few weeks after Mr. Holley's death, the following summary of the qualities of their deceased member was expressed by Hon. Abram S. Hewitt: "I think that even now, so soon after his departure, we can assign him to the place which he will hereafter occupy in the history of mechanical industry—a mechanical engineer of unerring judgment, an inventor of the true means for great results, a lover of his race, who subjected his science, his talents and his labor to the good of his fellowmen; and he will live in the memory of those who knew him, and in the grateful recollection of those who will come after him, for many a generation."

A list of Mr. Holley's literary works forms the seventh chapter of the memorial. The earliest mentioned paper bears the date 1850, three years before Holley graduated at Brown University. Many short articles are only referred to collectively in a foot note, but enough is clearly specified to prove that Mr. Holley was one of the most industrious of scientific men. He was the first editor of this Magazine, relinquishing it at the end of the first year on account of the pressure of his practical work.

House Draining and Sanitary Plumbing. By Wm. Paul Gerheid. New York: D. Van Nostrand. 2d edition, revised 1884. Van Nostrand's Science Series, No. 63. Price 50 cents.

The author is chief engineer of a company actively engaged in pushing improvements in this special line. The position is eminently adapted to produce a valuable book, if not too partisan. We do not observe the latter fault. On the contrary it appears remarkably fair in its enumeration and courses of the various devices in use in all the divisions of the subject from "Wash Basins" to "Trap on basin Drain."

He has managed to say a good deal on this vitally important subject in a 12mo book of 240 pages. The illustrations are peculiarly aggregated on larger sheets than the pages, and folded in. The inconvenience is more than balanced by the facility it affords for comparison. There is danger that with much use such illustrations will be detached, or at least mutilated. But it is a consoling reflection that the end is progressing with such strides that few will care to study these sections, except as curiosities, ten years hence.

The importance of being able to determine at moderate expense, in all situations, whether there are any considerable openings in the drainage pipes in a house can hardly be over estimated. The test of filling the interiors with a strong and marked odor has been long practiced by plumbers, and can be applied by any householder. It is described on pages 62 and 63.

An enumeration of five separate points on page 68 serves as a text for much of the succeeding portions. The book details, down to the latest steps of progress, how to attain these several points.

We pronounce this work, as now revised, the most practically important of this entire fifty-cent series. It is the most likely to do good by its extensive circulation. The community owes a debt to the author and publisher for disseminating this kind of information.

The Principles of Ventilation and Heating, and their Practical Application. By John S. Billings, M. D., LL. D. (Edinb.), Surgeon U. S. Army. The Sanitary Engineer, N. Y. 1884. Price $3.00.

Ever since the tailless animal reached the stage of refinement at which he commenced to avail himself of a covering of leaves, grass, turf, logs or snow, to defend himself against the heat, wet or cold, the question of how to live at the bottom of an ocean of air and have enough of it to breathe, has been before him.

Ever since Prometheus brought fire from heaven, or mankind some other way invented artificial warming, he has been confronted with the further difficulty—how to make fire available to ventilate; or, in many cases, has been obliged to "give it up," on the simpler problem—how to ventilate sufficiently in winter without too much cooling his building. This book is a valuable contribution towards its solution. But it shows that it is not yet solved.

Some forty years ago a wealthy gentleman of this city constructed a stable with an air passage from each stall out through the roof. His horses had colds all the time, till he closed them.

The Klamath Indian along the line between California and Oregon, in composing himself and his heterogeneous family for sleep in cold weather, lets the fire go entirely out, and then tightly closes the only orifice in his small earth hut. Exact scientific calculation, writes a friend of ours who was at one time surgeon at Fort Klamath, shows that they will all be dead at ten minutes before three. They perversely live and flourish.

This book is eminently a collection of facts, but these two facts are not in the volume. The chief fault one finds in reading it, with a desire to learn the latest, or rather the best plans, is the

absence of a clear statement of what the author recommends. He says, in substance, the amount of ventilation practicable with efficient warming depends on the expense which the owner is willing to incur in the construction, and in the subsequent fuel bills, a truism which no one can gravely dispute; but when we ask how to spend money, with tolerable assurance that the ventilation will be right so far as it goes without interfering with the warming, if the answer is there, it is not as conspicuous as we would like to see it. The United States Government expended liberally in ventilating the magnificent room—the House of Representatives in Washington.

Possibly some may consider the book better for omission of any recommendation. We do not. When one is familiar with the subject we deem it not quackery, but the opposite, the conclusion of one who has given much well-trained thought, observation and experience to his subject. To tell us how, it is due to the public. The preface tells us the object of the writer is "to present the general principles which should guide one in judging of the merits of various systems of, and appliances for, ventilation, more especially as applied to large public buildings." Engravings and descriptions are given of the provisions for warming and ventilating many buildings.

The elaborate description of steam-heating pipes, fans, distributing passages, and exhausting shafts in Mr. C. N. Dickenson's house, the Fifth Avenue Presbyterian Church (Dr. Hall's), Metropolitan Opera House, Madison Square Theatre, Union League Club, and Columbia College, New York; the south wing United States Capitol, and Barnes Hospital at Old Soldiers' Home, Washington; the House of Lords and House of Commons, London; Grand Opera House, Vienna; St. Petersburg City Hospital, Russia, and other buildings of less note, with his evidently fair statement of the remaining difficulties in most or all the cases, leave one with a painful sense of the little, instead of the much, which is known about ventilation. At Dr. Hall's church, he writes (p. 111); of Mr. Dickenson's house, our author writes (p. 69); of the latest and best result in the U. S. Capitol.

Our author gives with faint approval the leading features of the Ruttan system, a system devised by a wealthy Canadian, the late Henry Ruttan, who lost some members of his family by lung diseases, and spent the rest of his lifetime in devising and carrying out a plan of natural ventilation, excellent for dwellings and all buildings not crowded. We esteem the Ruttan system. Pouring the air in at the top and taking it out at the bottom deserving much more attention.

This book is valuable, immensely valuable. Its work is in a line beyond mere dollars and cents. Dr. Billings as author, and the Sanitary Engineer proprietors as publishers, are doing missionary work, in spreading light on this subject. If the light is foggy, it goes to show if any proof were needed that this subject is one which needs this book, and much still further skillful observation, experiment and successful practice with a still further wide-spread publication of the result.

MISCELLANEOUS.

In a lecture on the fixed stars, Dr. David Gill, F. R. S., said: "Light takes almost exactly 500 seconds of time to come from the sun; this is a figure easy to remember, and is probably exact to a single unit. The sun is ninety-three millions of miles distant, and this figure I believe to be exact within 200,000 miles. Quite recently the accuracy of these figures has been confirmed in a very remarkable way by different kinds of investigations by different observers, otherwise I should not have quoted them with so much confidence. The parallax of α Centauri is three-quarters of a second of arc; therefore its distance is 275,000 times the distance of the earth from the sun, and therefore light which travels to the earth from the sun in 500 seconds—*i. e.*, in $8\frac{1}{2}$ minutes—would take 4.36, or a little more than $4\frac{1}{3}$ years to come from α Centauri."

Rubennick's process for metalizing wood consists in steeping the wood in a caustic alkali for two or three days, according to its degree of permeability, at a temperature between 164 deg. and 197 deg. Fah. The wood is then placed in a second bath of hydrosulphate of calcium, to which is added, after twenty-four or thirty-eight hours, a concentrated solution of sulphur. After forty-eight hours the wood is immersed in a third bath of acetate of lead at a temperature between 95 deg. and 122 deg. Fah., where it remains from thirty to fifty hours. After a complete drying the wood thus treated is susceptible of a very fine polish, especially if its surface is rubbed with a piece of lead, tin or zinc, and finally finished with a burnisher of glass or porcelain. It then looks like a metallic mirror, and is completely sheltered from all the deteriorating effects of moisture.

Reports from the National Armory at Springfield, Mass., speak well of the new ramrod bayonet. The bayonet portion of the ramrod is 15 inches long, slightly thicker than an ordinary rod, with a four-grooved blunt point. It is held in position when ready for use by a simple spring clasp, invented by Col. Buffington, and when not wanted is pushed down until it occupies the same position as the ordinary Springfield rifle ramrod. On the experimental gun which has recently been fitted up according to Colonel Buffington's plans, a guarded bead front sight is used, and also a 2,000-yard screw adjustment peep hind sight, with a 1.4 inch windage movement. An automatic allowance for the bullet "drift" is one of the features of the new pattern hind sight.

A paper on "The Formation of Sugar in the Sugar-cane," was recently read by M. Aime Girard before the Paris Academy of Sciences. By comparative investigations of the amount of cane sugar and grape sugar in different parts of the sugar-cane in the afternoon and before sunrise, the author has found that only in the substance of the leaves does this quantity vary, and that the quantity of cane sugar sinks during the night to one-half, whilst the quantity of reducing sugar remains almost unaltered. He finds further that the quantity

of cane sugar in the leaves increases with the illumination, on very bright days reaching nearly one per cent., considerably less on dull ones, and in either case diminishing during the night by one-half. From this the author concludes that the formation of saccharose from glucose takes place entirely in the leaves under the influence of sunlight, and that the saccharose thereupon ascends the cane through the petioles, &c., and collects there.

IMPROVEMENTS IN BRONZE AND BRASS ALLOYS.—A patent has been obtained by Prof. A. K. Huntington for improvements in metallic alloys, the object of which is to secure strength, elasticity, and closeness of grain by the addition of a cheap and easily accessible material. For this purpose, to the copper or alloy he adds a small quantity of silicious iron which may contain a small proportion of other metals, such as manganese, tungsten, or the like. The mixture is made while the materials are in a molten state and as nearly as possible at the same temperature. As examples of alloys made according to the invention, to copper and tin in the usual proportion for gun-metal add not more than 2 per cent. silicious iron; to copper and tin in the usual proportion for brass add not more than 5 per cent. silicious iron; in bronzes or brasses where tin is present besides copper and zinc, a less proportion of silicious iron is used than when there is no tin. Generally, when zinc forms part of the alloy it is preferred to use silicious iron containing a proportion of manganese.

M. LAZARE WEILLER has conducted a series of valuable experiments with the object of ascertaining the relative electric conductivity of metals, submitting the results to the Société Internationale des Electriciens. They are referred to a pure silver wire, 1 millimeter in diameter, and having a resistance of 19.37 ohms per kilometer at 0 deg. C., as a standard. The following are his figures:—Pure silver, standard 100.00; pure copper, 100.00, silicon bronze (telegraph), 98.00; alloy of equal parts silver and copper, 86.65; pure gold, 78.00; pure aluminum, 54.20; silicon bronze (telephone), 35.00; pure zinc, 29.90; phosphor bronze (telephone), 29.00; alloy of equal parts silver and gold, 16.10; Swedish iron, 16.00; pure Banca tin, 15.45; 10 per cent. aluminum bronze, 12.60, Siemens steel, 12.00; pure platinum, 10.60; pure lead, 8.88: pure nickel, 7.89; antimony, 3.88.

M. EDOUARD LANDRIN, who had previously shown that when an intimate mixture, in certain proportion, of pure lime and quartz is raised to a white heat, the resulting cement sets slightly on contact with water, but becomes very hard in the presence of carbonic acid, has shown us the results of some new experiments on the hydraulicity of cements that (1) silicates of lime raised to high temperatures set with difficulty, and in any case do not harden in water, according to M. Fremy's experiments; (2) for the calcination of cements to exert a maximum influence on the setting, in connection with water, of the compound obtained, the process must be carried sufficiently far for the lime to act on the silica so as to transform it into hydraulic silica and not into fused silica; and (3) carbonic acid is an indispensable factor in the setting of siliceous cements, inasmuch as it is this substance which ultimately brings about their hardening.

MR. C. V. BOYS recently read a paper before the Physical Society on a phenomenon of electro-magnetic induction. Between the poles of an electro-magnet a small disc of copper is hung by a bifilar suspension. If the magnetic field is uniform and the disc at an angle to the lines of force, then on making the magnet it is jerked parallel with the lines of force. If it is a changing field, and the disc perpendicular to the lines of force, it is repelled on making the magnet and attracted on breaking by the nearest pole. This phenomenon, which was observed by Faraday, was shown by Mr. Boys to be useful for determining the intensity of a magnetic field by measuring the throw of the disc on magnetizing and demagnetizing. It might also be employed to measure the resistance of bodies in the form of plates, from their diameter, moment of inertia, and observed throw. Any structural difference of resistance in different directions in the body might be determinded by its means. Mr. Boys illustrated his remarks with curves of results obtained by experiment. Lord Rayleigh considered that the effect of self-induction on the results was not likely to be serious.

AN important piece of work has just been brought to a successful conclusion in Rome, in the complete renewal of the leaden envelope of the dome of St. Peter's Church, in Rome. It has occupied twelve years, and has cost over 200,000 lire (£8,000). The original covering was applied to the dome in an imperfect fashion, which made continuous repairs a necessity; and at last it was determined to strip off the whole envelope and substitute a new one on a better system. New lead was imported from Spain and mixed with the old lead, in the proportion of one part old to two parts new. The total weight of the new cover is given at 354,305 kilogrammes, and if it were spread out flat it would occupy an area of 6,152 square meters, or about an acre and a half. In stripping off the old plates three of them were found to be of gilded copper.

AT a recent meeting of the Berlin Physical Society, Professor Lampe spoke on the on the subject of a hypothesis respecting the formation of the solar system set up by M. Faye in place of Laplace's hypothesis. According to M. Faye's theory, in the original uniform nebular mass, vortices were formed which gave rise to the existence, first, of the middle planets, and then, ultimately, of the outer planets. This hypothesis was advanced as an explanation of the fact that the moons of Uranus and Neptune revolved in a direction opposite to that of the sun, the planets, and the other moons, a fact which was not accounted for by Laplace's theory. Only a brief communication, however, had yet been published of M. Faye's hypothesis, which, too, appeared to betray a number of lacunæ.

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BOILER EXPLOSIONS—THE CAUSE AND THE REMEDY.

By THOMAS KAYS.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

Since the introduction of steam as a motive power, and in the face of continuous investigation, the cause of steam boiler explosions has, until recently, remained a profound mystery. The theories of explosions were numerous. The most prevalent were "low water," "hot iron," "high pressure," "mere escape of steam," "superheated steam," "electrical," "gaseous," and the "spheroidal."

The theory most generally accepted was that of low water. This theory was in conflict with facts as established by unquestionable evidence, and therefore many refused to accept it.

The other theories were alike erroneous, and the result was much confusion of opinion upon the subject. The real cause was discovered by Daniel T. Lawson, of Wellsville, Ohio. He conceived the idea, and has fully demonstrated the fact, that water is an explosive, and that all steam boiler explosions are caused by the explosion of superheated water; that the explosion occurs upon a sudden reduction of pressure, followed by a sudden check to the exploding water, the result of which is a striking blow far in excess of the tensile strength of boilers.

The Lawson theory, briefly stated, is this:

The only explosive material about a steam boiler is water, and water, when superheated, which can be done only under pressure, will explode upon a sudden removal of that pressure, with a force quite equal to that of dynamite.

The boiling-point of water varies with pressure. In a vacuum, water boils at 70° sensible heat. Under atmospheric pressure it boils at 212°, and cannot be made hotter unless confined under additional pressure, because the escaping steam carries off the heat as fast as fire can impart it. In a steam boiler under 10 lbs. pressure it boils at 241°; 50 lbs., 300°; 100 lbs., 340°; 200 lbs., 389°.

Water when heated to the boiling point requires 966° additional heat to change it from the state of water to the state of steam. This change is substantially instantaneous at all pressures. As each molecule of water absorbs the last of the 966° it instantly explodes into steam. As the last degree is absorbed cohesion is overcome and repulsion becomes the predominant power.

The change of steam to water is also instantaneous. Steam remains in its new state only so long as it retains the 966° of latent heat, and the moment it is at full volume, with only 212° of sensible heat, parts with one of these degrees of latent heat, it returns to water.

The explosion of water is similar to that of gunpowder, in some respects, but different in others. Each grain of gunpowder passing from the solid to the gas-

eous state explodes when it has absorbed a certain degree of heat. So with water. Each molecule of water, at the instant it has absorbed 966° of heat above the boiling point, explodes and passes from water into steam. The expansive quality of the two is different, powder increasing in bulk 800 times, while water increases 1,720 times. The mode of exploding and the general result, large and sudden increase of bulk, are similar. In other respects they differ widely; the explosion of powder is by chemical action, the explosion of water is by physical change only.

Water differs widely from powder and all other explosives in another remarkable particular. Only a portion of the water may explode—one molecule, the half, or the whole mass. These various amounts in exploding produce results ranging from violent explosions to mild ruptures and the safe operation of the boiler.

When a grain of powder starts to go from the solid to the gaseous state no power can stop it. It may be confined, but combustion, once begun, goes on to completion. So with a molecule of water. It may be put under such pressure that it will not fully expand, but, once begun, it changes its state from water to steam.

The true source of the development of the great destructive power in a steam boiler is the sudden *concentration* of the sensible heat in the water above 212° (or above 70°, in case of a vacuum caused by the condensation of steam) into a part of the molecules of water passing into them the 966° necessary to change them from the state of water to the state of steam.

That the stored heat in a boiler concentrates to form steam is shown by familiar experiments.

As, for instance, causing water at less than 212° to boil by placing it in a vacuum; or, by merely condensing the steam overheated water in a bottle.

Again, take a steam boiler under pressure of 100 lbs., and a corresponding temperature of 340°. Remove the fire and the formation of steam will cease. After a short time raise the safety valve, and the water will begin to boil and generate and give off steam continuously as the pressure is reduced, until a temperature of 212° is reached, and enough steam will be thus generated and blown off to fill the boiler very many times.

These tests show that the boiling point of water is lowered by simply diminishing the pressure. They show this, and also show the true theory of boiler explosions. They prove in the most conclusive manner that the sensible heat above 70° stored in the water concentrates in a part of the molecules of water, giving to them the 966° necessary to change them into steam. The water ceases to boil. no heat is applied, and by merely reducing the pressure the water again boils. The 966° above the boiling point necessary to cause ebullition are not absorbed from the fire at the instant the water begins to boil the second time. They are already stored up in the water.

Take a boiler containing 10,000 lbs. of water at a pressure of 200 lbs. and a corresponding temperature of 389°. Suddenly reduce the pressure to 50 lbs. per square inch, under which pressure water explodes at 300°. There are stored in each of the 10,000 lbs. of water 80° of sensible heat above the exploding point —in the aggregate 800,000 thermal units, enough to convert 921 lbs. of this superheated water into steam. In an instant these 89° of sensible heat in each pound of water are absorbed by the molecules of water at the surface and for a considerable depth, and suddenly these 921 lbs. of superheated water explode into steam.

Thus, it will be seen that there is sufficient destructive power stored in the boiler when thus put in action to cause an explosion. If the reduction of pressure caused by the withdrawal of steam be moderate, and such draught be continuous and uniform, there will be no danger; but if the draught is considerable in quantity and instantly checked, the nascent steam thus suddenly formed and thus suddenly checked will give an *impact* or *striking blow* upon the shell of the boiler, the aggregate force of which is equal to the weight of the water before it passed into nascent steam multiplied by the square of the velocity with which it strikes.

The instantaneous check to the exploding water acts upon the boiler with the same effect as that produced by quickly closing the valve of a watermain. In the

one case it is the weight of the falling water, and in the other it is the force of exploding water, but the striking effect of the blows is the same, and is measured by the same rule.

Take a boiler 48 inches in diameter, 19 feet long, and place in it 10,000 lbs. of water. Then raise the temperature to 400°, and the corresponding pressure will be about 235 lbs. About $\frac{1}{200}$ part of the water, or 50 lbs., passes into steam, occupying the balance of the space of the boiler, about 86 cubic feet. The temperature is 188° above 212°. The amount of sensible heat, above 212°, stored in the remaining 9,950 lbs. of water is 1,870,600 thermal units, equivalent in mechanical energy to 1,444,103,200 foot-pounds. Suddenly reduce the pressure from 235 lbs. to normal. At 235 lbs. it required 400° to evaporate water, at normal pressure only 212°—a difference of 188°. There are stored in the boiler 1,870,600 units of sensible heat above 212°, enough to convert about 1,936 lbs. of the remaining water into steam, which would occupy, under 235 lbs pressure, about 3,000 cubic feet of space. Rating the velocity of the nascent steam at one-half the velocity of full steam discharged into the air (1967÷2), would give a striking force of over 23,000 lbs. per square inch upon the shell of the boiler.

Again, start with a pressure of 25 lbs. (at which the Westfield exploded in New York City, in 1871), and a corresponding temperature of 269°, and only 57° above 212°, and the amount of sensible heat stored above 212° would be 567,150 thermal units. Reduce the pressure to 0, corresponding to 70°, and the 9,950 lbs. of water would contain 1,980,050 thermal units, sufficient to convert 2,049 lbs. of water into steam. Rating the weight of the water and the velocity of the nascent steam as in the last case, this would give a striking blow of over 24,000 lbs. per square inch.

Take a boiler half full of water, under a pressure of 200 lbs. and at 389°, and suddenly inject into the steam space a quantity of cold water. Condensation is instantaneous. Instantly the superheated water at 389° is in a vacuum where it will explode at 70°. Under these circumstances a large portion of the water will explode into steam, and, whether one-quarter, one-half, or the whole, the striking force will be sufficient to tear into shreds any boiler ever made.

If the withdrawal of steam is slight, even if followed by a sudden check, no damage ensues with boilers of the usual tensile strength; but if the withdrawal be considerable and the check instantaneous, an explosion follows. With the varying degrees of draught and sudden check come violent explosions and mere rupture.

The distinction between *rupturing* and *exploding* is generally overlooked. When a boiler gives way at a weak point, resulting in damage, it is often called an explosion. When ruptured by mere pressure, the force exerted upon the shell being gradual and uniform, the weak point yields while the balance remains intact. Serious damage may result, but a uniform and unobstructed flow of steam never produces the phenomenon properly called an "explosion."

With an explosion the actual destructive force exerted is not measured by the tensile strength of the boiler nor by the regular pressure of the steam. The force is far in excess of either—five, ten, and often twenty times as great, an immense aggregate concussive and destructive force that tears asunder the weak and the strong parts at the same instant and demolishes everything within a large radius.

All writers on steam boiler explosions, in trying to account for their violence, have made the mistake of commencing the calculation at a point of time after the rupture has commenced. The fact is, there is violent internal action at the instant preceding the actual rupture of the boiler, and the rupture is the result of such action Rupture may be caused by the mere pressure of steam, but it is usually caused by an internal concussive force. It is certainly illogical to say that boilers are ruptured or burst by mere pressure while working with a pressure of only one-fifth their actual tensile strength.

The rational solution of a steam boiler explosion is this:

The water in the boiler under pressure is superheated, and possesses a highly expansive power. Upon a sudden removal of the pressure, without a corresponding reduction of the temperature,

it starts into violent evaporation. This mass of nascent steam is checked by coming in contact with the solid and unyielding shell of the boiler. The result is that the aggregate force of this nascent steam strikes every square inch of the shell of the boiler at the same instant and with the same force, and with a power far in excess of the tensile strength of the boiler; and, moreover, this force is augmented at the instant the shell gives way by an immense reserve power caused by the further evaporation of the water in the boiler.

This theory is in unison with natural laws, and upon it every explosion, bursting or rupture of steam boilers can be fully explained, and cannot be upon any other.

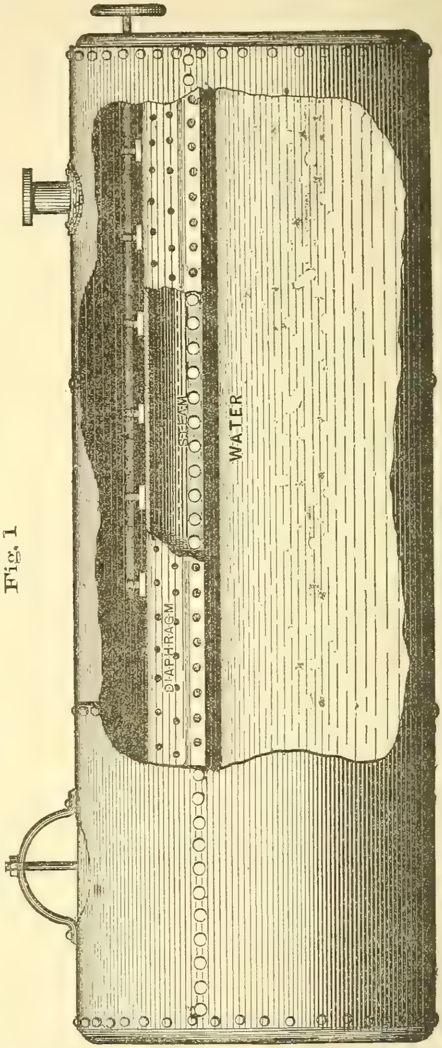
REMEDY.

Mr. Lawson, having discovered the cause, naturally turned toward the remedy, which is a simple one, and consists in the construction of a boiler with a partition plate, or diaphragm, dividing it into two compartments, the lower containing the water, and the upper containing steam only. The steam passes from the lower to the upper compartment through numerous small perforations and a number of small valves in the diaphragm. The aggregate openings of the valves and perforations should be less than the valve through which the engine is supplied. By this means the pressure upon the surface of the superheated water is kept approximately uniform, and all sudden explosions of any dangerous quantity of water into steam and consequent striking blows are avoided.

The diaphragm extends the length and width of the boiler, and is firmly riveted to the sides and ends thereof, as shown by figures 1 & 2. It may be circular or flat, and so located as to cut off about two-thirds of the usual steam space.

The perforations and valves vary with boilers of different size. The aggregate area of all the perforations and valve orifices should be about ten per cent. less than the area of the steam port. In ordinary-sized boilers there should be one perforation of one-quarter of an inch in diameter to each horse-power, rating ten square feet of heating surface to the horse-power, and such number of valve orifices of about two inches in diameter as to make up the balance of the aggregate area.

Fig. 1



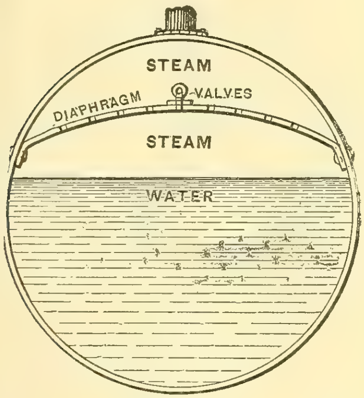
This lessening of the aggregate area ten per cent. below that of the steam port will give a very slight diminution of pressure in the engine with steam working at full stroke, but will practically give full pressure at every other point of cut-off.

There must be two steam gauges used, one connected with the water space below, and one with the steam space above, the diaphragm.

When the boiler is set and ready for use such small valves should be closed.

As the steam is generated and the engine put in operation at its full capacity, any additional steam required is obtained by gradually and partially opening such valves until the required amount is liberated and ascertained, when such valves are set, and need but little further attention. In thus arranging such valves particular attention should be paid to the steam gauges. The valves should be opened only to that extent at which the pressure upon the superheated water in the lower compartment, as shown by the gauges, remains approximately uniform with that in the upper, with the engine in full operation. Thus arranged, any unusual and sudden withdrawal of steam from the upper chamber is attended with no possible danger.

Fig. 2

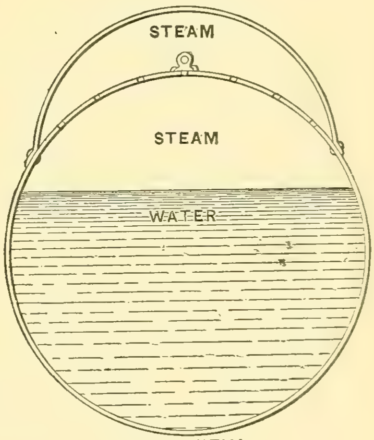


END VIEW

Boilers thus constructed and arranged are protected against explosions, whether the water wholly or partially fills the water compartment. If wholly filled a sudden reduction of pressure in the steam compartment can instantly affect only the surface of the water to the extent of the aggregate area of the perforations and valve orifices, and no dangerous quantity of water can be thus exploded. As the pressure upon the water below the diaphragm is thus slightly reduced, small portions of the water pass into steam and maintain uniformity of pressure.

If the water should get low, thus accumulating an unusual quantity of steam below the diaphragm, there can be no danger of an explosion. The discharge of steam from the ordinary boiler into the empty pipes and cylinder upon the sudden opening of the valves, is at a velocity of over 100,000 feet per minute, and for an instant there is a great reduction of pressure upon the surface of the superheated water. This cannot occur with the Lawson diaphragm in a boiler. With it the passage of steam from the water compartment below the diaphragm to the steam space above it is limited to that quantity used by the engine with the piston moving at the rate of, say, 600 feet per minute, and cannot exceed this precise amount to any great extent, although the steam may, from some unusual cause, be temporarily rushing from the steam space above the diaphragm fifty times as fast. The diaphragm limits the quantity of steam discharged from the water compartment to the exact amount necessary to drive the engine in full operation, and the liberation of this amount at such uniform rate can be attended with no possible danger.

Fig. 3



END VIEW

The Lawson diaphragm is to the steam boiler what the air chamber is to the hydraulic ram. It performs a similar, but much more important, function. The elasticity of the air moderates the otherwise solid blows of water upon the pipes; the diaphragm preserves uniformity of pressure upon the water, and thus prevents its explosion and the consequent violent and irresistible concussive blows upon the shell of the boiler.

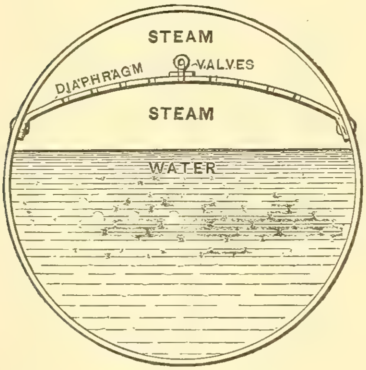
Explosions are thus prevented, not by extra strong boilers, but by preventing the occurrence of the cause. Boilers thus constructed can be safely operated at a pressure closely approaching their actual tensile strength.

The invention is applicable to every style of boiler, and can be readily applied, internally or externally to new or old boilers.

Figs. 1 to 7 fully illustrate the invention. Figs. 1 and 2 show an internal, and Figs. 3 to 7 an external application. Fig. 3, moderate pressure; Figs. 1, 2 and 5, high pressure, and Figs. 6 and 7, very high pressure.

Up to June, 1881, no person had ever intentionally exploded a boiler in accordance with any certain theory or plan, or with a knowledge of the true cause.

Fig. 4.



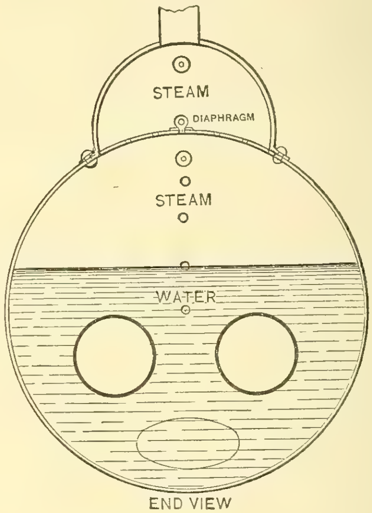
On the 16th of that month Mr. Lawson, at Munhall, near Pittsburgh, Pa., publicly tested his theory, and exploded a boiler of the ordinary style having a tensile strength of 768 lbs., at a pressure of but 290 lbs., being 478 lbs. less than the actual strength of the iron.

The experiment was made by suddenly discharging a considerable quantity of steam at 290 lbs. from the boiler into a closed cylinder, the explosion occurring the instant the cylinder was filled.

In March, 1882, he made further experiments at the same place under the inspection of a commission of U. S. engineers, appointed by the Secretary of the Treasury, and fully tested a boiler with his invention attached.

The boiler having the Lawson diaphragm, and being 30 inches in diameter, with only 18 inches of water, running down to 11 inches, 4 inches below the fire line, stood every test of rapid escape and sudden check of steam up to a pressure of 300 lbs., without the slightest injury. The same boiler, with the center of the diaphragm removed, reducing it to the ordinary-style boiler, with 22 inches of water, 7 inches above the fire line, was exploded at a pressure of only 235 lbs., 65 lbs. less than the boiler had withstood with Lawson's device, under precisely the same circumstances, except as to the quantity of water.

Fig. 5



High Pressure.

This discovery and invention remove all obstacles to the use of high pressure.

With immunity against explosion, higher pressure is safely secured, and with it greater power and economy attained.

The invention has other advantages of great importance.

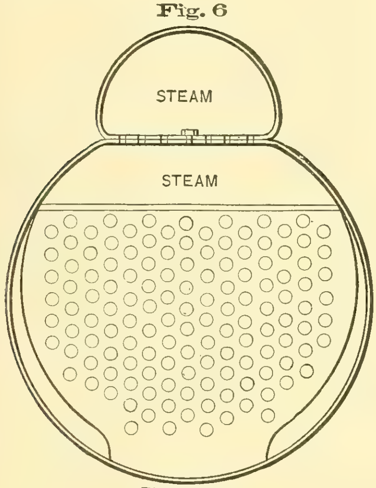
Dry Steam.

It produces dry steam, and prevents "foaming," "priming," or "entrainment."

The cause of these evils is that a large quantity of steam taken suddenly from a boiler at one point greatly reduces the pressure upon the water immediately under the point of exit, while the full pressure of the steam remains upon the surface of the water at every other point, and the result is that portions of the water are constantly forced out with the steam into the cylinder.

At each half stroke of the piston the sudden withdrawal of the steam from the boiler *at one point* in large quantities, while in direct contact with the surface of the water, decreases the pressure upon the water nearest the point of exit, causing it to rise up in the shape of a cone, while at all other points it is depressed below its former level, and by the sudden withdrawal of the steam in this manner, the pressure upon the water is at every half stroke of the piston reduced below the boiling point of the previous instant. The successive half strokes of the piston are followed by the cut-off of steam, which changes the pressure upon the water. This gives to the water a continual churning motion, the cone-

Fig. 6



shaped column of water rising at each half stroke and falling at each cut-off of steam, the balance of the water rising and falling correspondingly. This commotion is greatly increased by the pressure being changed at rapid intervals below the boiling-point of the water of the previous instant, thus causing the water to start into violent ebullition.

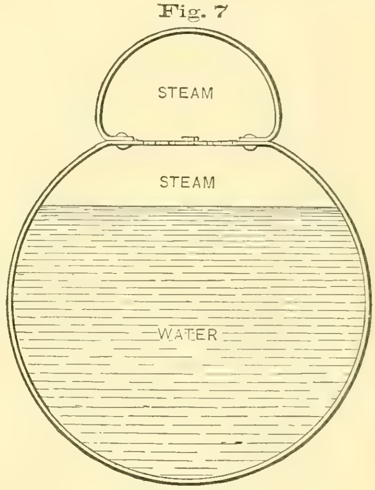
With the diaphragm, the steam passes from the lower compartment to the upper, not at one point, but in small quantities at many points; and the steam used being taken from the upper compartment, all the concussive force and intermittent pressure and motion are arrested and confined to the upper compartment, and the result is that the pressure upon the surface of the water is *uniform ;* there is no rising and falling of cone-shaped columns of water, no irregular pressure, no churn-like motion to the water, no irregular and violent ebullition.

Incrustation.

With boilers thus constructed, incrustation is wholly prevented. All foreign solid substances held in suspension or solution are separated from the water and deposited upon the diaphragm, where they do not interfere with the generation of steam and whence they can be readily removed.

This results from natural laws. All matter free to move occupies positions according to its specific gravity. Water in motion has the power of moving solids

Fig. 7



many times its own weight. Air, in only moderate motion piles up hills of sand, a substance two thousand times its own weight. Compressed steam has much greater power than air. The water and steam in a boiler have a rapid upward motion. Again, if the motion of the carrying substance is checked, the foreign matter it is carrying, if of a greater specific gravity, is dropped.

In the operation of a boiler with this device the greatest velocity of the steam is when it passes through the small orifices in the diaphragm, and the check comes when it is discharged into the upper compartment, and as the motion of the steam is checked it drops the sediment. Another law is that all sediment settles where there is the least motion.

There is still another operation constantly going on in this chamber which greatly aids in thus depositing the sediment. It is this, the steam is drawn from this chamber for use. At each cut-off of the supply of steam to the engine there is a slight intermittent motion to the steam in this chamber. At each cut-off there is a decrease in the specific gravity of the steam, resulting from the change of pressure, and this decrease of gravity and intermittent motion all tend to deposit the sediment. This boiler, therefore, with no other contrivance, thus forces the solid foreign substances in the water into the upper chamber before they have any chance to fasten themselves to the shell of the boiler.

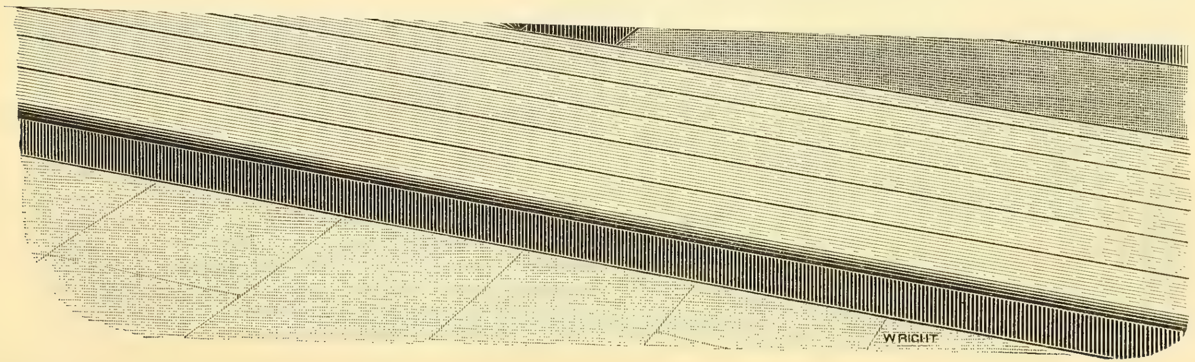
Thus, the mystery of boiler explosions having been solved, and a perfect preventive devised, accompanied by the attainment of dry steam, absence of incrustation, and safety with high pressure, are we not upon the threshold of a new era in the use of steam?

THE TEMPERATURE OF THE SOLAR SURFACE.

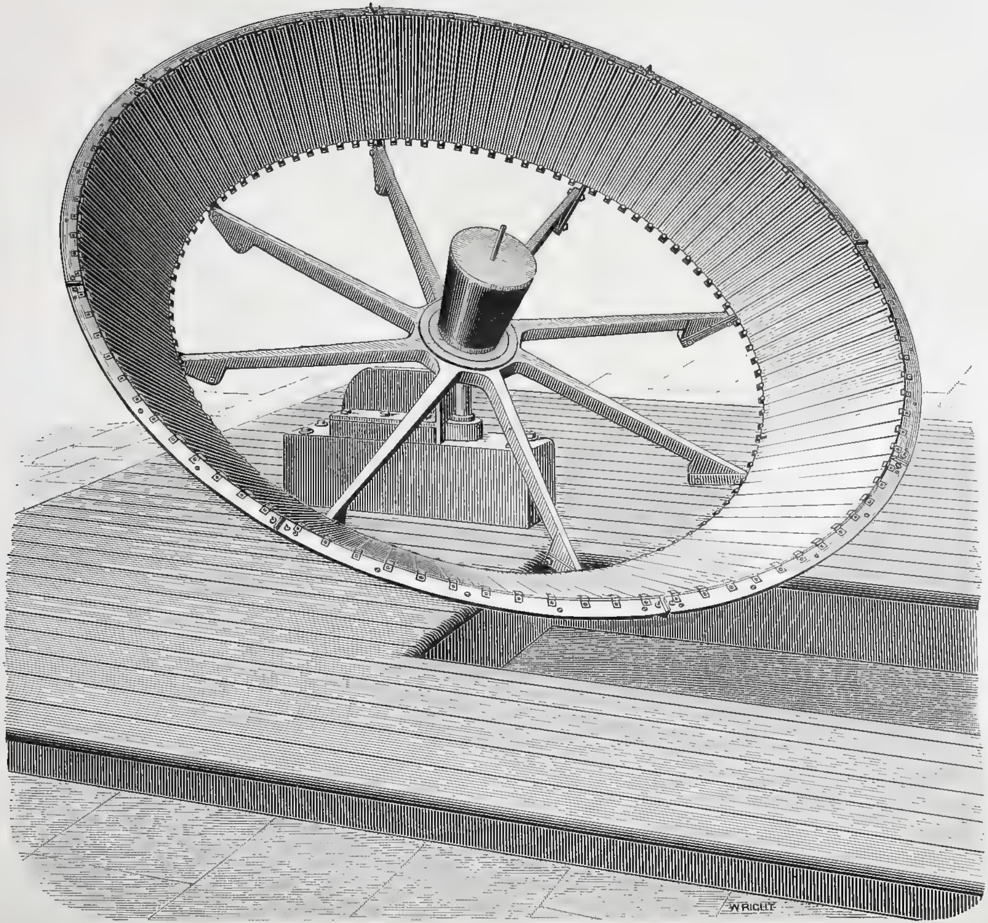
By J. ERICSSON.

From "Nature."

The power developed by the sun motor recorded in *Nature*, vol. xxix. p. 217, has established relations between diffusion and energy of solar radiation which prove that the temperature of the surface of the sun is extremely high. I have, therefore, during the summer solstice of 1884, carried out an experimental investigation for the purpose of demonstrating the temperature of the solar surface corresponding with the temperature transmitted to the sun motor. Referring to the illustrations previously published, it will be seen that the cylindrical heater of the sun motor, constructed solely for the purpose of generating steam or expanding air, is not well adapted for an exact determination of the amount of surface exposed to the action of the reflected solar rays. It will be perceived on inspection that only part of the bottom of the cylindrical heater of the motor is acted upon by the reflected rays, and that their density diminishes *gradually* towards the sides of the vessel; also that owing to the imperfections of the surface of the reflecting plates the exact course of the terminal rays cannot be defined. Consequently, the most important point in the investigation, namely, the area acted upon by the reflected radiant heat, cannot be accurately determined. I have accordingly constructed an instrument of large dimensions, a polygonal reflector (see Fig. 1), composed of a series of inclined mirrors, and provided with a central heater of conical form, acted upon by the reflected radiation in such a manner that each point of its surface receives an equal amount of radiant heat in a given time. The said reflector is contained within two regular polygonal planes twelve inches apart, each having ninety-six sides, the perimeter of the upper plane corresponding with a circle of eight feet diameter, that of the lower plane being six feet. The corresponding sides of these planes are connected by flat, taper mirrors composed of thin glass silvered on the outside. When the reflector faces the sun at right angles, each mirror intercepts a pencil of rays of 32.61 square inches section, hence the entire reflecting surface receives the radiant heat of an annular sunbeam of $32.61 \times 96 = 3130$ square inches section. It should be observed that the area thus stated is 0.011 less than the total foreshortened superficies of the ninety-six mirrors if sufficiently wide to come in perfect contact at the vertices. Fig. 2 represents a transverse section of the instrument as it appears when facing the sun; the direct and reflected rays being indicated by dotted lines. The reflector and conical heater are sustained by a flat hub and eight radial spokes bent upwards towards the ends at an angle of 45°. The hub and spokes are supported by a vertical pivot, by means of which the operator is enabled to follow the diurnal motion of the sun, while a horizontal axle, secured to the upper end of the pivot, and held by appropriate bearings under the hub, en-



Captain Ericsson's Solar Pyrometer, erected at New York, 1884.



Captain Ericsson's Solar Pyrometer, erected at New York, 1884.

ables him to regulate the inclination to correspond with the altitude of the luminary. The heater is composed of rolled plate iron 0.017 inch thick, and provided with head and bottom formed of non-conducting materials. By means of a screw-plug passing through the bottom

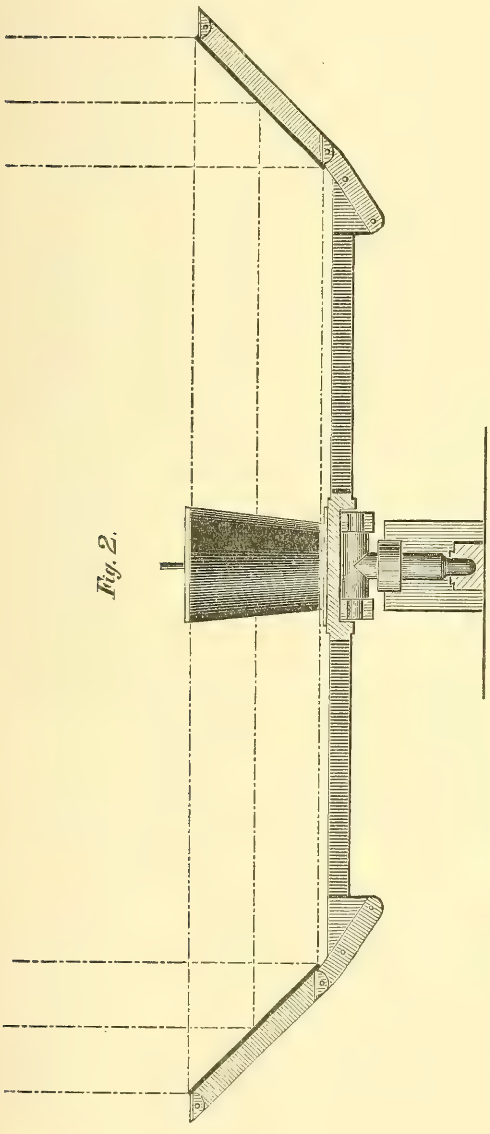


Fig. 2.

and entering the face of the hub the heater may be applied and removed in the course of five minutes, an important fact, as will be seen hereafter. It is scarcely necessary to state that the proportion of the ends of the conical heater should correspond with the perimeters of the reflector, hence the diameter of the upper end, at the intersection of the polygonal plane, should be to that of the lower end as 8 to 6, in order that every part may be acted upon by reflected rays of equal density. This condition being fulfilled, the temperature communicated will be perfectly uniform. A short tube passes through the upper head of the heater, through which a thermometer is inserted for measuring the internal temperature. The stem being somewhat less than the bore of the tube, a small opening is formed by which the necessary equilibrium of pressure will be established with the external atmosphere. It should be mentioned that the indications of the thermometer during the experiment have been remarkably prompt, the bulb being subjected to the joint influence of radiation and convection.

The foregoing particulars, it will be found, furnish all necessary data for determining with absolute precision the *diffusion* of rays acting on the central vessel of the solar pyrometer. But the determination of temperature which uninterrupted solar radiation is capable of transmitting to the polygonal reflector calls for a correct knowledge of atmospheric absorption. Besides, an accurate estimate of the loss of radiant heat attending the reflection of the rays by the mirrors is indispensable. Let us consider these points separately.

Atmospheric Absorption.—The principal object of conducting the investigation during the summer solstice has been the facilities afforded for determining atmospheric absorption, the sun's zenith distance at noon being only 17° 12′ at New York. The retardation of the sun's rays in passing through a clear atmosphere obviously depends on the depth penetrated; hence—neglecting the curvature of the atmospheric limit—the retardation will be as the secants of the zenith distances. Accordingly, an observation of the temperature produced by solar radiation at a zenith distance whose secant is *twice* that of the secant of 17° 12′, viz., 61° 28′, determines the minimum atmospheric absorption at New York. The result of observations conducted during a series of years shows that the maximum solar intensity at 17° 12′ reaches 66.2°

F., while at a zenith distance of 61° 28′ it is 52.5° F.; hence, minimum atmospheric absorption at New York, during the summer solstice, is $66.2° - 52.5° = 13.7°$ F., or $\frac{13.7}{66.2} = 0.207$ of the sun's radiant energy where the rays enter the terrestrial atmosphere.

In order to determine the loss of energy attending the reflection of the rays by the diagonal mirrors, I have constructed a special apparatus, which by means of a parallactic mechanism faces the sun at right angles during observations. It consists principally of two small mirrors, manufactured of the same materials as the reflector, placed diagonally at right angles to each other; a thermometer being applied between the two whose stem points towards the sun. The direct solar rays entering through perforations of an appropriate shade, and reflected by the inclined mirrors, act simultaneously on opposite sides of the bulb. The mean result of repeated trials, all differing but slightly, show that the energy of the direct solar rays acting on the polygonal reflector is reduced 0.235 before reaching the heater.

In accordance with the previous article, the investigation has been based on the assumption that, *the temperatures produced by radiant heat at given distances from its source are inversely as the diffusion of the rays at those distances. In other words, the temperature produced by solar radiation is as the density of the rays.*

It will be remembered that Sir Isaac Newton, in estimating the temperature to which the comet of 1680 was subjected when nearest to the sun, based his calculations on the result of his practical observations that the maximum temperature produced by solar radiation was one-third of that of boiling water. Modern research shows that the observer of 1680 underrated solar intensity only 5° for the latitude of London. The distance of the comet from the center of the sun being to the distance of the earth from the same as 6 to 1000, the author of the "Principia" asserted that the density of the rays was as 1000^2 to $6^2 = 28{,}000$ to 1; hence the comet was subjected to a temperature of $28{,}000 \times \frac{180°}{3} = 1{,}680{,}000°$, an intensity exactly "2,000 times greater than that of red-hot iron" at a temperature of 840°. The distance of the comet from the solar surface being equal to one-third of the sun's radius, it will be seen that, in accordance with the Newtonian doctrine, the temperature to which it was subjected indicated a solar intensity of $\frac{4^2 \times 1{,}680{,}000}{3^2} = 2{,}986{,}000°$ F.

The writer has established the correctness of the assumption that "the temperature is as the density of the rays," by showing practically that the *diminution* of solar temperature (for corresponding zenith distances) when the earth is in aphelion corresponds with the increased diffusion of the rays consequent on increased distance from the sun. This practical demonstration, however, has been questioned on the insufficient ground that "the eccentricity of the earth's orbit is too small and the temperature produced by solar radiation too low" to furnish a safe basis for computations of solar temperature.

In order to meet the objection that the diffusion of the rays in aphelion do not differ sufficiently, the solar pyrometer has been so arranged that the density, *i. e.*, the diffusion of the reflected rays, can be changed from a ratio of 1 in 5,040, to that of 1 in 10,241. This has been effected by employing heaters respectively 10 inches and 20 inches in diameter. With reference to the "low" solar temperature pointed out, it will be perceived that the adopted expedient of increasing the density of the rays without raising the temperature by *converging* radiation, removes the objection urged.

Agreeably to the dimensions already specified, the area of the 10-inch heater acted upon by the reflected solar rays is 331.65 square inches, the area of the 20-inch heater being 673.9 square inches. The section of the annular sunbeam whose direct rays act upon the polygonal reflector is 3,130 square inches, as before stated.

Regarding the diffusion of the solar rays during the investigation, the following demonstration will be readily understood. The area of a sphere whose radius is equal to the earth's distance from the sun in aphelion being to the sun's area as 218.1^2 to 1, while the reflector of

the solar pyrometer intercepts a sunbeam of 3,130 square inches section, it follows that the reflector will receive the radiant heat developed by $\frac{3,130}{218.1^2}=0.0658$ square inch of the solar surface. Hence, as the 10-inch heater presents an area of 331.65 square inches, we establish the fact that the reflected solar rays, acting on the same, are *diffused* in the ratio of 331.65 to 0.0658, or $\frac{331.65}{0.0658} = 5,040$ to 1; the diffusion of the rays acting on the 20-inch heater being as 673.9 to 0.0658, or $\frac{673.9}{0.0658}=10,241$ to 1.

The atmospheric conditions having proved unfavorable during the investigation, maximum solar temperature was not recorded. Accordingly, the heaters of the solar pyrometer did not reach maximum temperature, the highest indication by the thermometer of the small heater being 336°.5, that of the large one being 200°.5 above the surrounding air. No compensation will, however, be introduced on account of deficient solar heat, the intention being to base the computation of solar temperature solely on the result of observations conducted at New York during the summer solstice of 1884. It will be noticed that the temperature of the large heater is proportionally higher than that of the small heater, a fact showing that the latter, owing to its higher temperature, loses more heat by radiation and convection than the former. Besides, the rate of cooling of heated bodies increases more rapidly than the augmentation of temperature.

The loss occasioned by the imperfect reflection of the mirrors, as before stated, is 0.235 of the energy transmitted by the direct solar rays acting on the polygonal reflector, hence the temperature which the solar rays are capable of imparting to the large heater will be $200.5° \times 1.235 = 247.617°$; but the energy of the solar rays acting on the *reflector* is reduced 0.207 by atmospheric absorption, consequently the ultimate temperature which the sun's radiant energy is capable of imparting to the heater is $1.207 \times 247.617° = 298.87°$ F. It is hardly necessary to observe that this temperature (developed by solar radiation diffused fully ten-thousandfold) must be regarded as an *actual* temperature, since a perfectly transparent atmosphere, and a reflector capable of transmitting the whole energy of the sun's rays to the heater, would produce the same.

The result of the experimental investigation carried out during the summer solstice of 1884 may be thus briefly stated. The diffusion of the solar rays acting on the 20-inch heater being in the ratio of 1 to 10,241, the temperature of the solar surface cannot be less than $298.87° \times 10,241 = 3,060,727°$ F. This underrated computation must be accepted unless it can be shown that the temperature produced by radiant heat is not inversely as the diffusion of the rays. Physicists who question the existence of such high solar temperature should bear in mind that in consequence of the great attraction of the solar mass, hydrogen on the sun's surface raised to a temperature of 4,000° C., will be nearly twice as heavy as hydrogen on the surface of the earth at ordinary atmospheric temperatures; and that, owing to the immense depth of the solar atmosphere, its density would be so enormous at the stated low temperature that the observed rapid movements within the solar envelope could not possibly take place. It scarcely needs demonstration to prove that extreme tenuity can alone account for the extraordinary velocities recorded by observers of solar phenomena. But *extreme tenuity* is incompatible with low temperature and the pressure produced by an atmospheric column probably exceeding 50,000 miles in height subjected to the sun's powerful attraction, diminished only one-fourth at the stated elevation. These facts warrant the conclusion that the high temperature established by our investigation is requisite to prevent undue density of the solar atmosphere.

It is not intended at present to discuss the necessity of tenuity with reference to the functions of the sun as a radiator; yet it will be proper to observe that on merely dynamical grounds the enormous density of the solar envelope which would result from low temperature, presents an unanswerable objection to the assumption of Pouillet, Vicaire Sainte-Claire Deville, and other eminent *savants*, that the temperature of the solar surface does not reach 3,000° C.

ON THE MECHANICAL EXAMINATION AND TESTING OF PORTLAND CEMENT.

By HENRY FAIJA, Assoc. M. Inst. C. E.

From Selected Papers of the Institution of Civil Engineers.

It may be assumed that the object of testing cement is to ascertain its value for constructive purposes, and it is the aim of the author to examine the tests to which cement is generally subjected, and to see how far they attain their object.

The requirements of any test or combination of tests are, that the conclusion shall be absolute, and that the time occupied in arriving at that conclusion shall be as short as possible; and further, as all opinions formed by the examination of a cement must be based on the results of previous examinations and tests, it is evidently of importance that a uniform means of testing should be adopted, so that users and manufacturers may be able to compare their own tests with those by other people. At present the tests made by one person are of little use to anyone else, owing to differences of manipulation and detail.

The ordinary practice is to find the value of a cement by making it into briquettes and ascertaining their tensile strength when seven days old, as well as by its fineness, weight, and color; from the results obtained and their relative bearing to each other, a correct opinion is presumably arrived at.

Mr. Mann lately presented to the Institution the results of some experiments on the adhesion of cement to different materials, and by this means ascertained its value for constructive purposes. Nor must it be forgotten that Mr. Grant has introduced the sand test into this country from Germany, which is another test for adhesion; for although the briquettes made of cement and sand are tested for tensile strength, it is the adhesion between the sand and the cement which gives the briquette its tensile strength. Whether either of these enables a more definite conclusion to be arrived at than the ordinary method, the author does not venture to offer an opinion. He thinks, however, that neither of them is likely to supersede the generally accepted requirements of a test, and that therefore they are detrimental to the interests of uniform testing.

The author in this paper first considers the details of manipulation and other matters affecting the results obtained in a cement test, and afterwards the properties which a good cement should show in each detail.

In testing cement for tensile strength several points materially affect the result; namely, the percentage of water used in gauging. The skill of the manipulator, which practically means the time occupied in reducing the cement to a proper consistency, and the dexterity in filling the moulds, so that a sound briquette free from air bubbles may be obtained with the minimum of water in the minimum of time. The form and construction of the mould in which to form the briquette. The careful removal of the briquette from the mould and its subsequent handling. The time which elapses between the formation of the briquette and placing it in water. And the manner and speed at which the weight is put on the briquette when being tested.

It may be assumed that, as far as the tensile strength is concerned, a better result than can possibly be secured in practice should be obtained in the testing room; but it is of greater importance that a uniform result should be obtained by all persons engaged in testing cement, and that a uniform procedure should be adopted, than that the acme of perfection should be attained. The skill of the operator having a great deal to do with the result, it is necessary to reduce the operation of gauging the cement to, as nearly as possible, a purely mechanical process. This can be accomplished by a gauging machine devised by the author. It gives in ordinary hands as good a result as the most expert operator obtains when gauging in the usual way with the trowel. By employing the gauger the cement is

brought to a proper consistency to be put into the moulds in considerably less time; and by reducing the labor and wrist work necessary to properly gauge a cement, the inducement to slovenly manipulation and the use of more water than is necessary is obviated.

The advantage gained by adding the minimum of water for gauging has for sometime been acknowledged, and the results of experiments by Mr. Grant and others, and by the author, which have from time to time been published in the Proceedings of this and other Institutions, are sufficient to show that such is the fact. It is impossible to name a fixed quantity, as hardly any two cements require the same, and it can only be determined by making experimental pats previous to proceeding with the test. The maximum amount of water may, however, be fixed at 18 per cent.

That the time occupied in gauging a sample of cement effects the result obtained is hardly a matter to prove by experiment, it being evident that if cement is worked after it has commenced to set, its nature must be altered, and the result cannot be reliable; this, though it applies in a more marked degree to quick-setting cements, it is true of all.

The form of briquette must materially affect the result in testing for tensile strength. The author can only say that the form brought forward three years ago by Mr. Grant in a paper before this Institution, gives undoubtedly the best results, and he should like to see that form universally adopted. It is hardly necessary to add that the moulds should be of metal; resting on glass, metal or other non-porous bed. If a porous or partially porous bed is used, an excess of water in gauging is quickly withdrawn from the briquette, and the setting being thus accelerated, a better result is shown at short dates, though eventually there would probably be no difference. But inasmuch as a test of cement for practical purposes never exceeds twenty-eight days, and is generally confined to seven, a misleading result is obtained if this detail be not attended to.

The next item of importance is the time allowed to elapse between the gauging of the cement and placing the briquette in water. Experiments prove that the greatest tensile strength is obtained when the briquette is put in water directly it is set. With quick-setting cements this may be in an hour or two after gauging, and with slow-setting cements it may be extended to ten, fourteen, or twenty hours. The danger, however, is, that if this practice be adopted, in unskillful hands the briquette may be put in water a little to soon, when the cement would be acted upon detrimentally. It is therefore advisable that a given number of hours should be determined upon, and this by practice has been fixed at twenty-four hours.

In testing all other materials the rate of speed at which the weight or strain is applied is considered, but it seems to have been persistently ignored when testing cement. Its importance, however, must be as great with one material as with another. Mr. W. Matthews, M. Inst. C.E., and Mr. P. Adie, Assoc. Inst. C.E., have devised an automatic arrangement for running the weight along a steelyard, and it is fixed to most of Mr. Adie's testing machines. It ensures the weight being put on to the briquette at an even and regular speed, though no special speed seems to have been adopted. The principle on which it works is that of a falling weight governed by a water-brake. Dr. Michaelis' machine, in which the weight is applied by allowing shot to fall into a pan at the end of a compound lever, as well as Bailey's machine, in which water is used instead of shot, might both be easily arranged to apply the weight at a standard speed.

Notwithstanding the different results which it is evident would be obtained through variation in the speed of applying the weight, the author is not aware of any exhaustive experiments having been made, or any conclusion arrived at on the subject; he has therefore recorded the details of an experiment comprising over six hundred briquettes. The briquettes were broken at five different speeds, varying from 100 lbs. in one second to 100 lbs. in two minutes; these being considered the limits which it was possible to adopt in practice. By taking the average percentage of difference he has been enabled to draw a curve, showing the different results to be expected from applying the weight at different speeds. Though an experiment comprising only six hundred examples cannot

perhaps be considered conclusive, yet it enables a fairly good average to be obtained, especially as several different cements were used throughout the experiment. Although in each series the same cement was used, the gauging was all done at one time, and in exactly the same manner, by the same man.

The results were as follow:

Increase per cent. between 100 lbs. in 1 min. and 100 lbs. in 2 mins.,	3.960
Increase per cent. between 100 lbs. in 30 secs. and 100 lbs. in 1 min.,	3.528
Increase per cent. between 100 lbs. in 15 secs. and 100 lbs. in 30 secs.,	4.028
Increase per cent. between 100 lbs. in 1 sec. and 100 lbs. in 15 secs.,	10.726
Total per cent. between 100 lbs. in 2 mins. and 100 lbs. in 1 sec.,	23.142

The great difference shown by this experiment must impress every user and manufacturer of cement with the importance of adopting a standard speed at which the weight is to be applied; and it seems that the most convenient would be either the 100 lbs. in fifteen seconds, which the author uses in his testing room, or a little slower, but certainly not slower than 100 lbs. in thirty seconds, on account of the length of time which a test would occupy.

The author is of opinion that by adopting the before-mentioned or similar means and appliances for gauging the cement and priming the briquettes, the results obtained by different experimenters would approach more nearly to each other, a better estimation of the value of a cement would be possible, and a comparison would be more easily and more definitely decided.

The determination of the fineness of a cement can of necessity only be carried out in one manner, and is not subject to error. The weight per striked bushel, however, is open to considerable argument. The manner in which the measure is filled is of necessity all-important, it being assumed that the cement is to be put into the measure as lightly as possible.

As an alternative test or in conjunction with the foregoing, the specific gravity of a cement may be ascertained, with this advantage, that while the weight per bushel varies with the fineness to which the cement is ground, the specific gravity is of necessity constant.

The usual method of determining whether or not a cement will blow, is by making a few small pats and placing them in water as soon as they are set, which may be in one hour or two or more hours, according to whether the cement is quick or slow-setting, and by examining them daily to see if they develop cracks or otherwise alter in form. That the inference drawn from the result thus obtained is a true one, is extremely doubtful; and the author has thefore adopted another method to determine what, in his opinion, is the most dangerous property that a cement can possess.

Some years ago the author made numerous experiments with the view of accelerating the setting or hardening of cement and concrete, which resulted in his taking out a patent for that purpose. The process is only referred to because out of it has come a little apparatus of great value in the testing room, which enables a decided opinion to be formed within twenty-four hours as to whether the cement under examination will blow, or if it is a safe cement to use. The principle of the author's process for hardening is to subject the concrete immediately on gauging to a moist heat of about 90° Fahrenheit, and afterwards to keep it in a warm silicious bath at a temperature of about 100°. It was found that if by accident these temperatures were materially increased, the concrete sometimes gave all the appearance of having been made with a blowy cement. From this it was opined that a good cement would not blow at these temperatures, and further experiments have proved such to be the case, and also that a cement which does not stand this treatment is improperly made and will sooner or later blow. The author therefore devised an apparatus. It is a moist heat chamber and bath conbined in a small space; but the bath is only water instead of silicious. The mode of using it is to make a small pat of the cement under examination on a piece of glass and immediately to place it into the moist heat part of the apparatus. When it is set, which, even in the case of very slow-setting cements, will be within two or three hours, it is taken out of the moist heat chamber and placed in the bath. If next morning the pat is perfectly sound, it is decided that the cement will not blow; if, on the other hand, it is swollen and

blown, then the cement is considered unfit for use. It would not, however, be fair to say that because under these conditions the pat was blown, it is an improperly made cement, for the blowing might be due to extreme freshness,

Under these circumstances, therefore, it is necessary to put a small quantity of cement on a tray in a thin layer, and to let it thoroughly cool for two or three days. If a pat made from this cooled cement blows when submitted to the influence of the moist heat and warm bath, the author would on no account advise the use of the cement. On the other hand, if it does not blow, it is pretty clearly shown that the cement is sound but too fresh, and that the bulk should be turned over three or four times and cooled before use.

The author proposes in the second portion of the paper to consider the properties which a good and useful cement should develop when being tested, under three divisions; firstly, those properties which have already been amply experimented upon, and which may be considered as proved and acknowledged; secondly, those which may be termed the problematical, which though inherent to a good cement may also be found in a bad one; and thirdly, the absolute strength and behavior of the cement at different dates.

Of the first, it may be considered that both users and manufacturers are cognizant of the importance of a cement being finely ground, and that, given a certain cement, the best result is obtained when it is finely ground. There is, however, a limit which commercially cannot be exceeded, except of course at an increased price, or until other machinery has been invented for grinding. This limit seems to be that the cement shall all pass through a sieve having 900 meshes to the square inch, and shall not leave more than 10 per cent. residue on a sieve having 2,500 meshes to the square inch. This degree of fineness is for all practical purposes sufficient; and if a user thinks he can obtain a better result by having a finer ground cement, he should be prepared to pay a higher price for it.

The weight per striked bushel specific gravity or density of a cement, are in the highest degree problematical tests. It is assumed that a heavy cement means one with a proper quantity of lime in its composition and well calcined, and a light cement the reverse; but it does not of necessity follow that such is the case. It is also possible to have a cement too heavy, and, as pointed out by the author ten years ago, and by others since, the weight must bear a definite relation to the fineness. Of necessity the finer the cement, the lighter it will weigh. It is generally considered that a cement of the fineness previously specified should weigh from 110 to 114 lbs. per striked bushel, when the bushel measure is filled in a manner similar to that adopted by the author. The specific gravity corresponding to this weight and fineness is from 3.00 to 3.08.

The color of a cement is almost too problematical to deserve consideration, except when examining cements made from similar materials, as the varying properties of different raw materials must of necessity affect the color. But the author puts very little value on these problematical tests as a means of assisting in the determination of the value of a cement.

The absolute behavior of the cement when made into briquettes and tested at different dates, and the careful examination of its behavior during gauging and setting, are the best means for determining its value for constructive purposes.

The determination of what the tensile strength of a cement should be at certain dates, is the one point on which all authorities seem to differ, and yet it is the one test which has been experimented upon more than all other tests put together. If, however, all the experiments which have been published are examined, it does not seem difficult to arrive at a just conclusion. The author has made thousands of tests in this direction; he has examined all the tests which have been published in England, and some of those from Germany, and the result of these tests and examinations is, that good cement, which practically continues to increase in strength for a period over which it is possible to make a test, has a tensile strength, when tested in the ordinary manner, of not more than 300 lbs. or 350 lbs. per square inch at the expiration of seven days from gauging; while the same examination shows that many of those cements which at the same age carry 400

lbs. or 500 lbs. actually deteriorate before they are a year old.

The author is of the opinion that the strength at a single date does not define with sufficient accuracy the value of a cement; but that two dates should be determined upon, and the increase per cent. in strength between those dates will better define the nature of the cement than the actual strength at either. As an example, the two following cements may be cited:—

—	3 Days.	7 Days.	28 Days.	3 Months.
No. 1......	390	460	520	510
No. 2......	205	375	490	590

Consider the behavior of No. 1 cement up to twenty-eight days. It is superior in every way to No. 2; though the increase of strength between each date is but little, while No. 2 increased 85 per cent. between the three and seven days, and 30 per cent. between the seven and twenty-eight days. The latter therefore appears, as indeed is proved by the result of a three-months' test, to be still increasing in strength, and likely to do so for some time, while No. 1 is a cement which develops all its strength in a short period. It is therefore not likely to increase in strength with age, and may possibly deteriorate. It would not, however, satisfy the case to define only the increase per cent. which should take place between certain dates; but a minimum and maximum strength should be determined upon at the earlier date, as indicative of a good cement, and a specified increase above that for all future tests named. In the author's opinion, the tensile-strength of a briquette three days old should be at least 175 lbs., and should not exceed 275 lbs. per square inch; the increase of strength between the three days and seven days should be from 40 to 50 per cent.; and if a twenty-eight days' test is adopted, the increase should be from 20 to 30 per cent. of the strength shown at the seven days.

A slow-setting cement does not practically increase in temperature during setting; it is only the quick-setting ones which develop this characteristic. Many quick-setting cements when fresh will increase in temperature as much as 16° and 18° Fahrenheit in eight or ten minutes from gauging, and will not return to their normal temperature for more than an hour. If cement possessing this characteristic be cooled, it will be slower setting, and the increase in temperature during setting will not be so great. This test may therefore be often useful in assisting in the immediate determination of the value of a cement.

The author maintains that there should be a uniform standard specification, compliance with which would ensure a thoroughly good and sound cement, which manufacturers would be able and willing to supply at the ordinary market prices. A standard specification has been for many years adopted in Germany and other countries, and has proved of great benefit to the industry, and there is no reason why it should not be equally beneficial in this country. Shippers, and users who require only a few hundred tons at a time (and it must not be forgotten that these take up the bulk of the cement made in this country), know that they were obtaining a good and useful article. Such an arrangement would in no way interfere with engineers, or others who use large quantities, adopting their own specification, and there is no doubt manufacturers would be prepared to comply with their demands under special conditions. In order, however, to ensure success, a standard specification should be one which, while meeting all requirements, should be simple and conclusive, and at the same time expeditious. In nine specifications out of ten, many of the items demanded are contradictory, and many often useless. It therefore seems necessary to examine the clauses usually inserted in a specification, and see what assistance they render in determining the value of the cement, so that the actual clauses in a specification may be reduced to a minimum. Taking them in order, they generally appear to be: first, the weight; second, the fineness; third, the examination of pats; fourth, the color; fifth the tensile strength at seven days; sixth, that the cement shall set in a certain time.

Notwithstanding that this hitherto has been considered a good and efficient test, the author believes no correct estimate of the value of the cement can be arrived at by the comparison of the results ob-

tained, and therefore would substitute for them the following:—

First, fineness; second, absence of blowing, determined by the use of the apparatus already described; third, the tensile strength at three and seven days, and the increase per cent. between those dates. In addition, a twenty-eight days' test might be adopted if practicable; but in many cases—certainly in all cases of shipment—it is impossible to allow the examination of the cement to extend over such a long period.

TEMPERATURE OF THE SUN.

By DeVOLSON WOOD, M. A., C. E.

Written for Van Nostrand's Engineering Magazine.

This most important point in Mr. F. Gilman's criticism, in the last September number of this magazine, of my article in the last July number, is whether the law of the inverse squares as applied to heat is applicable to extended surfaces. If his assertions be taken in place of proof, little need be said; but on this point there is a show of reasoning, inasmuch as he asserts that "gravitation, light and radiant heat conform to the same law." In examining the truth of this assertion, we begin with the fundamental principle of the attraction of matter—that the attractive force between any two particles varies directly as the products of their masses and inversely as the square of the distance between them; thus expressed $\frac{mm'}{r^2}$. The law has no existence in reference to a single material particle only, as Gilman seems to imply. Do light and Mr. radiant heat necessitate two bodies, one to impart and the other to receive? But the law especially referred to is that of the inverse squares. Can it be said of gravity that the force varies inversely as the square of the distance unless there be an external body, so that there may be mutual action between them? Is it necessary to have an external object in order that the intensity of heat shall vary inversely as the square of the distance? (Admitting the law, for the moment). In the case of gravitation, is not the attractive pull (so to speak) the same on both bodies, regardless of their relative size? And is this the same with light and heat? The answers to these questions are evident, and are only made to show fundamental differences.

Mr. Gilman says: "But it has been proved that the same law of gravitation prevails in a spherical homogeneous mass of any dimension, when the distance is measured from the center"—a statement partly true and partly false. He here confines his attention to *one* body, and in that sense it is not correct. In the next place, assuming that he would have the action of the sphere upon a particle, it is not true if the particle be within the sphere, for in that case it is found that the attraction upon the particle at the center of the sphere is zero, and increases as the distance from the center to the surface. Is this true of a hot sphere? Is it true that there is no heat at the center of such a sphere? And does the heat increase from the center outward? Answers are unnecessary. But for fear that it may be said that this is not a fair case, it will be well to observe that this law of increase of gravity in the homogeneous sphere is deduced from the fundamental law of gravity between particles.

But it may be properly claimed to be true for the attraction of a homogeneous sphere upon an external particle—or, to be more precise, for the attraction *between* such a sphere and an external particle. But it must be observed that this "has been proved" by means of the law relating to the attraction *between particles*; and in this proof it is assumed that the attraction between the external particle and the most remote one of the sphere is precisely the same as if they were the only particles considered. In other words, the attraction is the same whether bodies intervene or not. Has it been proved that the same law holds for

radiant heat in this case? The above result may be thus stated: The attraction between two homogeneous spheres is the same as if their entire masses were concentrated at their respective centers. Can a similar statement be made of radiant heat? If so, where is the proof? Further, by means of the fundamental principle above stated, the principle holds for gravity when the spheres are not homogeneous, provided only that each of the concentric spherical shells of which the spheres may be conceived as composed, are of the same density, but varying from one to the other in any manner. When Prof. Tait is correctly reported, it will be found that he does not support the theory that the law of the inverse squares "is also applicable in the case of heat radiating from a spherical body, such as the sun." We do not understand how Mr. Gilman can insist upon this law of the inverse squares in this case and at the same time admit that the law of Petit and Dulong is reliable even to nearly 400° F., since the latter is entirely at variance with the former. I suppose that both of us have typographical errors in the notation of the formula

$$Q=1.146fa^t.$$

In my article it should have read $a=1.0077$, and Q should be substituted for r, and with these corrections the formula was sufficiently correct for my purpose, though not exact; but if the formula quoted by Mr. Gilman gives better results, or results more favorable to Captain Ericsson's theory, we are willing he should profit by it. It is safer to extend an approximate empirical formula beyond the limits of strict applicability, than to use a principle not founded on reason or experiment. We made no claim for accuracy of the result, but simply showed that, according to recognized theories, the temperature of the sun might be about 5000° Fahr.

But Mr. Gilman asserts that the law of the inverse squares "gives the temperature of the medium in the vicinity of the body" and "Capt. Ericsson has proved the temperature of the medium in the vicinity of the sun is at least 1,303,640° Fahr." What medium is here referred to? Is it the luminiferous ether? If so, who can say that it is not diathermanous? Or is some other medium referred to? The assertion is a bold one.

Finally, let Mr. Gilman extend his calculation, by assuming that the body is 400,000, 100,000, &c. miles from the center of the sun and determine its temperature!

GERMAN REGULATIONS AS TO THE CONSTRUCTION OF IRON BRIDGES.

From "The Engineer."

At a meeting of the German Association of Architects and Engineers held in October, 1881, the question of normal regulations for the delivery of iron structures for bridges and buildings was discussed. The subject was then referred to the Saxony Association, for the drawing up of a series of regulations on the subject. The matter has since that time been under consideration, and during last autumn the work projected was accomplished.

In the scheme drawn up—signed by Messrs. Centner, Ehrhardt, Frankel, and Fritzche—the question of bridge construction has been treated in a comprehensive manner; less attention having apparently been given to that portion of the subject which refers to building work. The following is a summary of the principal features of the scheme in question, given in detail by the *Wochenblatt fur Architekten und Ingenieure.*

I. Technical basis of construction: (A) *Intrinsic weight of the structure;* (B) *Alterable vertical load.*—(*a*) In railway bridges this is represented by a train consisting of three of the heaviest locomotives in prospective use, and an unlimited number of loaded goods trucks. (*b*) The traffic on road bridges consists of foot passengers and carriages. For

main girders of bridges, of about $65\frac{1}{2}$ ft. span, concentrated loads upon one or two axles are more unfavorable than the burden of a crowd, but in the larger bridges the latter is the most unfavorable. This last-named pressure can as a rule be estimated at about 82 lbs. per square foot, but in cases of a compact crowd the pressure may be as high as 114 lbs. per square foot. The prospective burden of carriages has to be estimated according to the probable character of the vehicles and the description of roadway; the portion of the roadway not covered with vehicles being supposed to be filled with a crowd. In some cases regard must be paid to a probable load of street locomotives. (*c*) In buildings the movable burden of the floors, burden of snow on the roof and wind pressure. (C) *Horizontal forces.*—(*a*) The wind pressure acting horizontally may be estimated for the loaded bridge at $30\frac{3}{4}$ lbs. per square foot, and for the unloaded bridge at $51\frac{1}{4}$ lbs. per square foot, or, in a specially exposed situation, even at $57\frac{1}{4}$ lbs. per square foot. (*b*) In curved railway bridges the effect of the centrifugal force for the maximum speed of the trains has to be taken into consideration. (D) *Allowable requirements of the material used in the construction.*—The employment of the formulas founded on Wöhler's tests is suggested, but the following strengths are mentioned as maximum requirements: Welded iron, 7,625 tons per square inch; steel, 11.5 tons per square inch. Wide flanged welded iron I girders—where the width of the flanges exceeds that of the German normal profile—even if they have only to support a fixed load, should not be required to stand a test of above 5 tons per square inch in tension. In calculations affecting rivets there should not be more strength claimed than about 3.75 tons per square inch of rivet section. Cast iron should be required to stand tests for extension of 1.625 tons per square inch, and for pressure of 4.75 tons per square inch.

II. Preparations of contract drawings and calculations.—III. The preparation of working drawings.—The drawings and calculations on which a contract is based are, as a rule, prepared by the building authorities, and when the adjudication takes place the contractor receives attested copies. If these are—apart from the general plan—on the scale of one-twenty-fifth to one-twentieth of the natural size for entire main girders, and one-tenth the natural size for the details, no further working drawings are required. Any defects arising in the work are not to be excused on the ground of want of clearness or imperfections in the drawings. Any changes suggested by the contractor are to be notified within a given period. When special working drawings are to be prepared by the contractor, they are to be submitted in duplicate to the building authorities within a given time after the adjudication. Any purchases of materials or other steps taken before the approval of these working drawings are at the contractor's risk. The calculations as to weight are in most cases prepared by the authorities and annexed to the contract. If they are in accordance with the dimensions shown in the drawings no further calculations of weight are required, but the contractor is bound to examine them. Should approximate weights only have been given, the contractor is bound to send in within a given time in duplicate an exact calculation of weights. The following standards of weight are to be taken as a basis:—Cast iron, $452\frac{3}{8}$ lbs. per cubic foot; wrought iron, $486\frac{1}{4}$ lbs. per cubic foot; steel and ingot iron, $490\frac{5}{8}$ lbs. per cubic foot.

IV. Selection, quality, and testing of the materials.—(*a*) The bearing portions of the structure, such as the main girders, cross girders, and intermediate girders, as well as all portions which are liable to deflection, are in general to be made of wrought iron. It is recommended in bridge building to use wrought iron instead of cast iron columns. As to the use of mild steels, caution is advised in the present conditions of methods of manufacture. (*b*) The definition of the quality of the material of the construction must be governed by its working capabilities. (*c*) The wrought iron used must at least possess the qualities specified in the conditions of classification issued in May, 1881, by the Association of German Ironworks. As to mild steel and ingot iron, tests can hardly be specified on account of the insufficiency of experience relating to them. The cast iron portions must be cleanly made of grey soft iron in the prescribed dimensions. They must

contain neither blisters, holes, fissures, nor any other defects. The minimum strength must be—against tension 7 tons per square inch; compression 38 tons per square inch. Cast iron columns and supports are tested up to double the burden for which they are constructed. The minimum thickness of metal for cast iron columns is $\frac{2}{5}$ inch.

V. Cleaning and painting.—Previous to the separate parts being put together —plates, bars, &c.—the rust and hammer slag are to be removed from the iron. The mode of cleaning is left to the contractor's option, but he must give notice of what it is, and is responsible in the instance of chemical cleaning for any subsequent rusting arising from want of care in the removal of the acids used. The cleaned portions are to be coated with a varnish of boiling hot linseed oil, which must be thin and quick in drying. Until dried, the portions thus coated must be properly sheltered. The building authorities are at liberty to arrange for a provisional acceptance when the riveting is completed, after which the grounding of the parts may be effected with a protecting ground paint. For this purpose a varnish of linseed oil with red lead is recommended, but the operation must not take place during damp weather in the open air. This provisional acceptance is not any agreement on the part of the building authorities as to the correctness of the measurements or the number of pieces in the construction. The larger portions are only to be grounded on the building site after revision. After the iron portions are in position, all the joints are to be carefully filled up, at the surfaces of contact, with a putty composed of white lead and linseed oil varnish, and a grounding of red lead is to be applied to the heads of the rivets driven in on the building site. Besides, all spaces between portions of the construction where water might accumulate have to be carefully filled up with asphalt. The entire construction subsequently receives from the building authorities a second coat of oil paint. Should the zincing—galvanizing—of any portions be prescribed, it should be effected by a strictly uniform coating. The portions thus treated should be capable of being bent until they break without the zincing, *i.e.*, what is incorrectly called galvanizing in this country, becoming detached. The coating of zinc must be as free as possible from lead.

VI. The manufacture and putting together of the separate parts.—All the parts of the construction must exactly correspond with the drawings and fulfill the following conditions:—(*a*) The portions fastened with rivets or screws must fit closely together. (*b*) All iron portions must be rolled or forged out of one piece of iron, and not be formed by the welding together of separate pieces. Any exceptions have to be specified. (*c*) Angles and bending are to be avoided as far as possible. (*d*) The rivet holes must correspond as to diameter and position with the drawings. The holes which are drilled at the building site should be about $\frac{1}{25}$ of an inch narrower than the diameter of the rivet requires, so that a good fit is insured after its being enlarged. (*e*) All screw holes and rivet holes are to be carefully drilled. (*f*) Where several holes meet each other in the parts to be united, a horizontal dislocation of not more than 5 per cent. of the diameter of the hole is allowable. The holes must, however, be made perfectly equal with the rimer, and not by filing on one side. Rivet bolts of proportionately large size must be used in holes thus enlarged. (*g*) The rivets are to be inserted at a bright-red heat—after being carefully freed from scales—into the duly cleared rivet holes in such a manner that they are quite firm after the head is completed. (*h*) After the riveting, it is to be tested whether the rivets are quite firm. All that are not firm or do not correspond with the above-named conditions are to be removed and replaced by others. No further driving is under any circumstances to be permitted in the cold state. In the putting together of the parts, care is to be taken that none of them is forced into a one-sided tension. Should any portions become distorted in the riveting, the connections must be loosed and the faults carefully remedied.

VII. Extent of completion in the workshops.—In all parts not to be riveted in the factory, provisional screw bolts must be inserted. Riveting upon the building site is to be confined to the smallest possible extent, and, therefore, the completion of all possible parts of the work at the factory is recommended.

VIII. Suspension of the execution and acceptance of the work in the workshop.—The building authorities have the right of constant or occasional skilled supervision of work in the workshops, and the necessary appliances and force for tests and examinations must be furnished to them, or obtained by them at the contractor's expense. All portions not according to the prescribed regulations, or otherwise unserviceable, are to be marked in such a manner that their subsequent employment in the structure may be recognized. The examination of the iron material and the control of the execution in the workshop does not prevent the rejection of the work delivered, during or after the erection of the structure, if defects show themselves.

IX. The mode of ascertaining the weight.—For the purpose of computation all parts of the structure should, if possible, be weighed, but when this is impracticable, a certain number of objects selected by the building committee should be officially weighed for the purpose of obtaining reliable indications regarding the total weight of the structure. The computation then takes place according to the agreed prices on the basis of the total weight as ascertained, if the latter does not exceed the original computed weight by more than 3 per cent. If the excess of weight is more than 3 per cent., the contractor is only paid for 3 per cent. extra. Any shortness in weight is deducted. Portions of a structure which are more than 5 per cent. above the estimated weight, or more than 2 per cent. under it, can be at once rejected.

X. The stonework of bridges.—The bed stones are delivered to the contractor in the correct position of altitude, and the middle line of the bridge construction is marked on the pillars in a distinct manner. The contractor is supposed to ascertain by his own measurements, before the erection begins, the exact dimensions, and to control the same according to the drawings, reporting any differences to the building authorities, and awaiting their decision; otherwise the contractor is liable for any ultimate difficulties. The contractor is specially bound to carry out the correct and exact placing in position of the main girders. The masons' and stone-dressers' work in connection with the final works is looked after by the building authorities, who likewise provide the necessary materials.

XI. The erection on the site.—The methods to be employed in the erection of the ironwork and of the scaffolding are generally left to the judgment of the contractor, but the building authorities have the right in letting out the contract to stipulate for a certain mode of erection. The machinery for hoisting and other appliances have to be supplied by the contractor at his own expense. As the erection of scaffolding, &c., is subject to local regulations, the building authorities are to give the contractor, in the conditions for delivery, all available information, plans, &c., bearing on this point, as also upon the question of land and water transport for materials, &c. Plans of the scaffolding—scale 1:100—are to be submitted within a given time after the adjudication—by the building authorities to the local officials for examination and approval. Those parts of the masonry on which the bed-plates are to be placed should be put at the disposal of the contractor a given time before the date fixed for the completion of the ironwork. Should the masonry not be ready, the contractor must be apprised of the altered circumstances, but any compensation under this head must be a stipulation of the contract. The officials charged with the supervision of the erection are authorized to satisfy themselves in any way they wish as to the quality of binding materials not yet tested. A repetition of tests for strength already carried out in the workshops can only be ordered by the building authorities in special cases. The contractor is bound to follow the instructions of these officials within three days, but has the right of appeal to the building committee. In urgent cases the officials have the right to order the suspension of the work, but if it is found on appeal to the building authorities that such a course was not justified, the contractor is entitled to compensation for any injury he has sustained, and the period of suspension is added to the time originally fixed for the execution of the work.

XII. The testing and acceptance of the completed work: (a) super-elevation of girders.—Truss and lattice girders, &c., are laid with a camber, which is computed upon the principle that after the

work is finished and the load has produced its natural effect, there should remain a camber equaling half the bending which would have been produced by a similar moving load.

(*b*) *Tests for load.*—These vary according to the purposes of the structure. Railway bridges are tested by a train being placed on each of the lines. This train consists of three of the heaviest goods engines available, the first with the chimney in front and the two others with the chimneys in opposite direction to each other, and loaded goods trucks of the heaviest description in use upon the railway in question. These trains are placed upon that portion of the bridge which corresponds with the greatest momentum, and the amount of deflection after six hours is measured in the center of the main girders and at the main piers. The train is then removed and the amount of permanent deflection of the girders is ascertained. Finally the bridge is crossed at the maximum speed allowed upon the line, and the amount of transitory and permanent deflection is ascertained. For testing road bridges a testing weight is brought upon the roadway and the footpaths, where it is left for twenty-four hours. A row of the heaviest loaded vehicles which have been provided for in the construction of the bridge is driven step by step over it, and is then allowed to rest half an hour upon it. In both cases the transitory and permanent deflection of the main girders is ascertained, as previously explained. The marching of men in time, as well as the rapid driving of vehicles over the bridge, are not excluded, but must be provided for in the conditions for the construction. The most unfavorable combination of the burdens of the separate openings is produced with continuous girders. A small permanent deflection after the removal of the first trial load cannot be attributed to any defect in the construction if no permanent deformation of the separate parts of the work can be proved. Further trials should, however, not produce any further deflection. The measured elastic deflection with fixed and moving loads must not in any case exceed the computation by 15 per cent. Any differences in temperature which may have intervened should be regarded in such tests. All defects which are rendered visible by the tests, and which can be traced to faulty execution or to the materials used, are to be remedied by the contractor within a period fixed by the building authorities. The tests for burden are carried out at the expense of the building authorities. The examination of the work with a view to its acceptance as a whole should take place within a given period of its completion. The contractor remains answerable for a certain period as to the normal condition and the good and proper execution of the work. It is suggested that a year is a suitable period.

ON WATER SUPPLY.

Papers read before the Conference of the Society of Arts on the Water Supply held at the International Health Exhibition in July.

From the "Journal of the Society of Arts."

I.

Water Supply in Its Influence on the Distribution of the Population.

BY W. G. TOPLEY, F.G.S., ASSOC. INST. C.E.

One of the most essential conditions for the comfort and well-being of a population is water, and a little consideration will show that the early settlements of a people have been where, and only where, water occurs.

In a broad and general sense, this fact is patent to all—the banks of rivers and streams are usually well populated—the wide areas of waterless districts are unpeopled; but the fact is equally true in a very limited and restricted sense, not at first so obvious.

The source of all water is the rain which falls on the land; this acts in two different ways, according to the nature of the soil on which it falls. If the soil is porous, or pervious to water, a certain portion of the rain sinks in; if the soil is impervious, the whole of the water either drains off the land into brooks, or passes back by evaporation into the air. The

water which soaks into a porous soil or rock, accumulates there until it flows out again as springs, or is artificially tapped, and drawn away by means of wells.

Springs occur near where a pervious bed overlies or underlies an impervious bed, or where a valley reaches down to the level at which the rock is saturated with water. In the case of valleys cutting deeply into the rock, the valleys themselves determine the level of saturation.

A soil which allows water to sink into it is a dry soil, and is, therefore, suited for habitation and for agriculture. Hence the main conditions which favor the settlement of a district are found in the same soil, or along the outcrop of the same bed. We thus see that geological structure controls the distribution of the population; not only in such great features of the earth's surface as mountain-chains, plains, and valleys, but also in the minor divisions of the district.

The outcrop of a narrow band of porous rock, between wide beds of clay, is strongly marked by the occurrence of a long line of villages, each of which obtains its water from shallow wells or springs. The cornbrash, between the Oxford clay and the great oolite clays, is an excellent example of this. So, too, is the marlstone rock-bed, between the upper and lower lias. Even a thin and comparatively unimportant bed of sand, ironstone, or limestone, if it only affords a small space fit for arable culture, will be marked by a line of villages. A thin bed of ironstone in the lower lias of Lincolnshire is a good example of this.

When rocks rise from beneath a covering of clay there are often springs at the junction.

The base of the chalk escarpment, with the line of outcrop of the adjacent upper green sand gives another good example. Here the villages always lie thickly along a definite line. There is a well-marked and constant relation between the outcrop of porous strata and the parish or township boundaries, the longer axes of the parishes crossing the outcrops more or less at right angles. A careful study of the distribution of the villages, and of the relation of their parish boundaries to the main physical features, throws much light upon the past history of the country, and often enables us to determine the relative ages of the settlements. This branch of the subject does not now concern us; we need only note that the arrangement of the parish boundaries depends upon the sites of the settlements, and that these are controlled by the outcrops of water-bearing beds.

The early settlements in England were nearly always controlled by such circumstances as have been here referred to; but the later development of special towns and districts has depended upon a variety of circumstances. In early times it was around some shrine of special fame or sanctity, or under the shadow of the castle of some powerful noble, that the population clustered and the town increased. A little later it was also in places especially well suited for various manufactures. Within the last 200 years the great development of our mineral wealth (especially of coal and iron) has entirely transformed the country. Large towns have sprung up over the coal-fields, often on wide tracts of clay, where few settlements would otherwise have taken place. The natural surface water supply of such places is often bad and small, and the mining operations frequently drain even this.

The water supply of modern towns is, in nearly all cases, either (*a*) obtained from a neighboring river, (*b*) brought from a distance, or (*c*) obtained from deep wells beneath the town. It thus, except in the first case, differs from that of the original settlement, which always obtained its water from streams, springs, or shallow wells. In far too many cases the primitive source of supply has been continued in use long after the time when it should have been abandoned; and the local source of water supply, essential to the early development of a town, has become a source of danger as the population has increased.

Of the points just mentioned, London affords an excellent example. The old parts of London and its suburbs are built upon gravel resting on London clay. Where small valleys (such as the Fleet) cut through the gravel, there are natural springs; but everywhere water can be obtained in shallow wells sunk through the gravel. So long as the inhabitants were dependent entirely upon these springs and wells, the houses were confined to the gravel; when a general sys-

tem of water supply was introduced, the population extended over the intervening area of clay. Meanwhile, the increasing population, without any adequate system of drainage, fouled the shallow wells, and rendered them all more or less impure. It is only within the last few years that some of these have been closed by authority.

Below the superficial deposit of gravel, there are other sources of water supply for London. The strata beneath lie in a basin-shaped form, and thus favor the accumulation of water. Underneath the London clay there are the lower tertiary sands, holding water which rises in the wells when these are sunk through the clay. Still lower, there is the great mass of chalk in which there is an enormous store of water. Still lower, and separated from the chalk by a bed of clay (gault), is the lower greensand. This, on the south side of London, may yet yield some water, but it can never be the great source of supply which was once hoped for.

There are, then, with the river, four different sources of water supply at or beneath London, each giving a different quality of water. Probably no large city in Europe is better situated than London for supplying itself with water from within its own area; but so vast has London now become, that all these taken together are insufficient, or inefficient.

It is a curious circumstance that some others of the great capitals of Europe are built on "basins" like that of London, and hence are able to obtain deep well-water from beneath. Paris, Berlin, and Vienna are good examples. This is a circumstance that could not have been known to the early settlers, who concerned themselves only with the surface sources of water supply.

The Origin of Water Supply.

BY G. J. SYMONS, F. R. S.

This title might possibly be supposed to imply a history of the past, but in this Health Exhibition, *pace* Old London, we deal chiefly with the present and with the future.

I know no better word than origin wherewith to describe the small portion of the great subject of water supply which I am permitted to discuss.

All water supply comes from the clouds, and it is with the products of the clouds as rain (including therein snow and hail) that I have to deal.

Perhaps, before describing the general features of rainfall distribution, it may be permissible to explain (for the use of those who have never done it) how the fall of rain is measured. If we imagine a flat dish—a tea-tray, for instance—placed upon a lawn during rain, it is obvious that (subject to loss by splashing) that tray would, at the end of the shower, be covered by a layer of water of a depth approximately equal to that which fell upon all portions of the lawn, and the depth of water on it (say $\frac{1}{2}$ inch) would be the depth of the rain fallen. Obviously, besides the loss by splashing, the water on this tray would soon evaporate and be lost, besides which the depth could not easily be accurately measured. For these reasons, some form of funnel is always used, so that the rain may be, as it were, trapped, prevented from splashing out, and from evaporating. In the gauge before you (a very inexpensive one) all known sources of error are guarded against, and, as the water collected by a 5-in. funnel is measured in a jar only $1\frac{1}{2}$ inches in diameter, it will at once be seen that its vertical depth is multiplied nearly tenfold, and, therefore, even one-hundredth of an inch is easily measured.

There are other patterns specially adapted for observation on mountain tops, where they can only be visited once a month; others for observations during heavy thunderstorms, so as to obtain data needful for drainage questions; others in which every shower that falls writes down its history, the instant of its commencement, its intensity during every minute, and the time of its termination; but I must not stand between you and other papers with a discourse on the many interesting points which these gauges bring out.

During the last 25 years I have done what I could towards establishing a complete system of recording the rainfall in this country. In early days the British Association for the Advancement of Science gave considerable help, but some ten years since they dropped it. Government have never given any help at all, and now the whole cost, or 99 per cent.

of it, is borne by the observers themselves, a body which has now grown to the very large number of nearly 3,000. I do not know the precise number, but there are every year new stations beginning, old ones stopping, and others interrupted; yet, for 1883, I have just had the pleasure of printing perfect records from 2,433 stations, every record having been previously carefully examined and verified.

Hitherto I have been so overworked, and my staff has been so small, that the discussion of the data falls behind the collection; for this reason I cannot lay before you such data as I wish. However, the map on the wall is the one I drew many years ago, and which was inserted in the sixth report of the Rivers Pollution Commission. It is not perfect, but as it is tinted with increasing darkness for places with heavy annual falls of rain, it will at least show you the broad features of the distribution over the country.

I refrain from going into the subject in detail, desiring chiefly that you should realize the fact that large tracts of country have twice and even three times as much rain as others. If we descend to single stations the differences are, of course, greater, *e. g.*, in 1883, the rainfall at the Stye, in Cumberland, was 190.28 inches, and at Clacton-on-Sea, in Essex, it was only 18.71 inches; that is to say, the one was more than ten times the other.

Here I should like to interpose a question as to public policy. There is often a great outcry if the water of one district is taken to another. Surely, while there is no relation whatever between the density of population and the quantity of rainfall, one early duty of a Government is to see that all parts are amply supplied with the chief necessary of life. Englishmen have a dread of centralization, but in many ways they pay a long price for their dread. At present it is not often that any town can even state before Parliament its views as to the effect upon it of what its next neighbor may be obtaining powers to do. Having suggested one semi-legal question, I may as well mention at once another. Up to the present time, there being no Hydraulic-office (as I hold that there should be) in this country, all the larger water questions come before Parliament as private bills, and, provided that they get through committee, they, as a matter of course, become law—law for all time to come. No one can foresee what will be the total population of this country a century hence. No one can tell where the bulk of the people will reside, nor what will be the need for water in various parts of the country. Water-rights are already very valuable, and they will probably become still more so. Would it be possible to safeguard our successors by insisting that special water-rights, if now asked to be created, shall be subject to revision, *without compensation*, after the lapse of 100 years?

However, to return to rainfall, and explain why I stated it to be the origin of water supply. All rain and melted snow must be disposed of, either by evaporation, percolation, or flow into streams and rivers. The first class, evaporation, is, of course, not a supply, and therefore we must not pursue it. Percolation is the source of all springs and of all well-water. Sometimes, as at Lancaster, the springs are so large that even a considerable town can be supplied by merely laying pipes to the sources whence they burst forth; sometimes they run into the reservoirs of gravitation waterworks; sometimes they pass, as in the chalk districts, for miles beneath impervious strata, finally being either pumped up from wells, or even, in rare cases, rising as true artesian wells above the surface of the ground; and sometimes they pass even deeper, as in the red sandstone supplies pumped from extreme depths for Liverpool and other towns.

The water which runs off the surface is sometimes utilized by throwing a bank arcoss a stream, and thereby forming a reservoir behind it, as, for instance, in the new supply for Liverpool from the Vyrnwy, where the reservoir will form a lake larger than many of those in Cumberland. Sometimes the lakes themselves are utilized as reservoirs, as, for instance, Loch Katrine and the surrounding lakes, and sometimes, as at York and London, the rivers are drawn from by powerful pumping machinery.

It is often said that there are few things so uncertain as the rain. That is both true and false. True as regards

our ignorance of the future, false as regards our knowledge of the limits within which the quantity of rain will be found to vary.

There are now hundreds of records of rainfalls in this country of thirty or more years each, and in a very large majority of them it will be found that the following proportions will be within 7 per cent. of the truth:

Wettest year, 45 per cent. more than the average.

Driest year, 33 per cent. less than the average.

Driest two consecutive years, 26 per cent. less than the average.

Driest three consecutive years, 21 per cent. less than the average.

There are many other facts respecting the laws of rainfall distribution, concerning which time prevents my saying anything, but I trust that enough has been said to establish the necessity of a perfect system of rainfall registration as the basis of any efficient hydraulic organization.

Water Supply to Villages and Rural Districts.

BY EARDLEY BAILEY-DENTON, C.E., B.A., OXON.

I believe that I am uttering a fact which no one can discredit when I state that there is no object in social economy which is more important, having regard to the aggregate number of persons affected by it, than the supply of water to village communities and rural districts.

At the present moment, when the International Health Exhibition may help to draw attention to sanitary objects of varying degrees of importance, it may be well to make clear that the condition of rural districts, in relation to water—the first essential of healthy life—is a positive disgrace to a country represented by a State Department whose efforts, it appears to me, should be specially directed to the protection of small communities less able to help themselves than large ones; and is a sad reflection on the present advanced stage of sanitary knowledge—an admission which the special meteorological condition of the present season, and a possibility of a visit of cholera, brings home to all minds with increased force.

If it should be understood, too, that the existence of this condition of things is to be traced, not so much to the absence of potable water, or the difficulty of bringing it into use, as to the disinclination of local authorities to develop the capabilities at their command.

It may be said with truth that, as a general rule, Local Boards and Boards of Guardians having jurisdiction in rural districts, who have been called into existence to supply the sanitary requirements of those districts, are animated with less desire to perform the duties devolving upon them than to avoid them. It is, indeed, notorious that the majority of members of Local Boards are elected under a pledge to oppose such works as sewage and water supply, on the ground that the rates will be increased, and knowing this to be the case, and that few persons of superior position are willing to take part in Local Boards, because they would invariably be outvoted, it is easy to understand why rural districts should be the last to move in the water question. It is, however, very difficult to explain why the clergyman and medical man of rural parishes, whose higher education should be a guarantee that the right thing would be done, fail to exercise proper influence. If, perchance, they are elected to serve on Local Boards it almost invariably follows that the one forgets what he has said in the pulpit as to the influence on the future of sudden death; whilst the other ignores the advice he has given his patients in their sick-chamber in relation to the fatal effects of inhaling and imbibing those germs of disease which float in foul air and impure water. Directly they are easy in their chairs as members they content themselves with the *laissez faire* policy of their colleagues.

These influences explain how it is that local authorities abstain from appointing as surveyor, or sanitary inspector, any man with a capability and courage to expose local defects and requirements, and why, when a medical officer does his duty in explaining the defective character of the water supply of any portion of his district, some reason is soon found for relieving him of his duties, and for appointing another in his stead, the actual result of all this being that the governing bodies of rural and small urban

districts exercise their functions, when compelled to act, not by taking the advice and opinion of men technically qualified to guide them, but by the exercise of their own judgment. You may often observe a small publican or a grocer—excellent tradesmen in their respective vocations—directing the sinking of wells in village streets in close proximity to leaky sewers, ditches or cesspools, by which the water intended for the supply of the poorer inhabitants soon becomes foul and unsuitable for domestic use. So general, indeed, has been this abuse, that it is no exaggeration to state that nineteen out of twenty existing village wells are quite unfit for their purpose, and that if samples were honestly taken and submitted to a competent analyst they would be condemned. Yet they are permitted to exist, and nothing is said about them, because the populations interested are comparatively small, the death rate is not excessive, the dwellings are low in value, and, above all, because the rates would be increased if a proper water supply were substituted.

I have been induced to offer some remarks upon the present occasion, not because I have anything especially new to lay before you, but because the facts I have just referred to on the constitution of local authorities and the performance of their duties, have been made more pertinent by the circumstance that, at a time when there exists the apprehension of a visit of cholera, a scarcity of water may occur, owing to a remarkably dry winter being followed by an unusually hot summer, which the recent thunderstorms may not sufficiently counteract. It is unnecessary to explain that the summer supply of water is very greatly dependent upon the fall of rain during the preceding winter, *i. e.*, upon the rain falling in the non-evaporating and dormant months of November, December, January and February. The mean amount of rainfall in those months of the last winter did not reach two-thirds of the average quantity due to the same months for the preceding 60 years. This deficit would have been much more severely felt at the present time, and would have affected our subterranean supplies much more than it is now likely to do, had it not been in some measure counterbalanced by the excesses of rain which occurred during the last seven years, from 1876 to 1883, which gave us, on the whole, a considerable balance to carry over. This advantage, coupled with the frequent and heavy thunderstorms which have occurred within the last month or two, will go far to prevent the scarcity of water which would otherwise have occurred during the coming autumn; though, unfortunately, this national advantage will be a poor compensation to the agricultural interest, which has suffered so severely from the excessive wetness of the last few years.

Without taking into consideration on the present occasion the use of rain water, which, under careful management, may be collected from roofs and other impervious surfaces, and stored in tanks, and which will always form a valuable means of supply to private dwellings, and in special instances may be made available even for villages, our rural supply, now so often derived from dirty ditches and shallow wells, more or less polluted by foul matters, may, in the absence of springs, rivulets and impounded upland surface waters, be obtained from subterranean sources of "wholesome" character. These are to be found in various beds or outcrops of a water retaining character, which gather water at a comparatively shallow depth below the surface, such as the post-tertiary beds of Norfolk and Suffolk, and the different drift beds covering the London clay; the Bagshot sands, the green sand overlying the wealdon and gault clays, the surface sands and beds of the wealdon formation, the calcarious grit and coral rag outcropping between the Kimmeridge and Oxford clays, and other beds of like nature; or from the well-defined water-bearing strata of the chalk, the oolite, and the red sandstone formations which are deep lying, and to reach which it is often found necessary to pass through superincumbent impervious beds or strata of varying thickness.

From the first source it requires comparatively little motive power to raise the supply to the height required; in fact, in many cases, the application of the ordinary lift or atmospheric pump suffices; in others, where the depth exceeds thirty feet, additional power is called for. The second source requires more powerful pumping, and may involve

the use of several pumps working in unison. All this has been said and explained before. My desire now is, if possible, through the influence of this meeting, to impress upon Local Boards and Boards of Guardians in rural districts, where, in order to obtain unexceptional potable water, they are obliged to seek it beneath the surface, that the experience already gained in tubular wells goes far to prove that, in the majority of instances the "tubular" system may, with good effect, take the place of the old and more expensive practice of sinking large wells involving brickwork, steining and staging. Economy, important though it be, is however secondary to the more important fact that a tubular well signifies continuous and watertight piping from the surface of the ground to the subterranean water level beneath, so that the entrance of polluted surface or subsoil water (as is so frequently the case in ordinary shaft wells) is rendered impossible. In addition to this advantage, it should be pointed out that tubular wells are very rapidly made, and can be readily removed should it occur that the water found or sought has not answered expectations in quantity or quality. Moreover, the whole of the materials employed may be applied, when withdrawn, to the same purpose in another place.

I may here state that there are some few disadvantages attending the adoption of tube wells which it is right at once to refer to. One is, that if, owing to accident, pumping is stayed, there will be no supply during such time, and if it should happen that the stored supply should run out before the pumping is resumed, much inconvenience may be experienced; whereas in ordinary shaft wells, there being room for more than one pump, such an objection may be obviated. Another disadvantage is that should the demand for water increase beyond the capability of supply the only remedy is to sink others, and to utilize two or more in combination.

To render the nature and cost of tubular wells, which necessarily vary in character and size according to local circumstances, as intelligible as it is possible to make them to rural sanitary authorities, I may shortly state that, adopting for illustration, the two characters of the tubular wells already mentioned, *i. e.*, those that can be worked by ordinary lift and atmospheric pumps at a depth of less than 30 feet from the surface, and those that raise water by more powerful machinery from deep subterranean water-levels, the *modus operandi* and cost will be as follows:—

In the first instance, taking, as examples, cases where the populations may severally be 400 and 1,000, and where there exists a constant supply of water at 20 feet below the surface, recourse may be had to Norton's Abyssinian tube wells. The water is reached by driving tubes down through the ground to the water level. The first tube is pointed and perforated for a few inches with holes varying in size from $\frac{1}{8}$ to $\frac{1}{4}$ inch. Length after length of tubing is driven into the earth at the selected site, and each succeeding length is connected with the last by a screw joint. The perforations at the base are four times as much as is necessary to obtain the full flow of water from the tubes, and they are kept clear by an arrangement adopted by Messrs. Legrand and Sutcliff, of Bunhill Row, City, for forcing out any sediment or matter that may obstruct a free influx of water. This is effected by suddenly liberating a column of water after it has been raised to a sufficient height above its normal level. The number of tube wells required in a village of 400 would probably be two, and in one of 1,000 people probably five. From figures kindly given to me by the patentees it would appear that the capital expended in providing the wells and appliances will not exceed 2s per head of the population. Of course this only refers to the provision of the tubes, the pumps, and the cost of fixing them. There are many instances of small villages and hamlets where one well and pump alone would suffice; but there are others besides those given as illustrations, where a number of these wells may be necessary, and which should be united by means of a cast iron horizontal main or mains, with intervals between the vertical pipes, governed by the nature of the water-bearing seam out of which the water supply is obtained. This distance may vary from 18 to 30 ft. The motive power to work the pumps may vary in kind; water-power may be used when it is close at hand, or gas where it can he readily obtained.

In the second instance (deep sources), the tube wells consist of iron piping fixed in bore holes, which latter, in fact, form the well, with the piping to serve as the pump barrel and rising main, to raise the water into a service reservoir. These bore holes will vary in depth according to local features, and in diameter from 5 to 15 inches, according to the quantities of water to be raised. The core of pipes form as already intimated, a continuous tube from the surface of the bore hole to the water level below, and are made perfectly flush both inside and out, and must be watertight. They are sunk for a sufficient depth below the standing water level as to secure an effective discharge. The pump is fixed within the tubing, which forms a cylinder, and is connected with the engine on the surface by rods properly guided within the tube. Special pains are taken so to construct and fix the pump that it may be readily brought to the surface, repaired, and replaced. For the first 15 or 20 feet of the well a shaft 5 or 6 feet in diameter is necessary, in which to fix the necessary gearing connecting the engine with the pump, and to place the air vessel, &c., regulating the lifted supply to the reservoir. It would appear from figures supplied me by Messrs. Tilley, of Walbrook, for works which we have now in hand, that the primary outlay varies from £500 in a case where the lift is 100 feet, the supply 40 gallons per minute, the depth of the bore hole 300 feet, and its size 7 inches, to £750, where the lift is upwards of 250 feet, the supply 50 gallons per minute, the depth of the bore-hole over 300 feet, and its size 9 inches.

Besides tubular wells sunk perpendicularly into subterranean water, supplies may not infrequently be obtained by the use of siphons for drawing water out of water-yielding basins, to which there is no natural outlet, by deflected pipes laid over or through the rims of the basins. The extraction of the required supply is effected by dipping the shorter leg of the siphon into the water bed forming a ready-made reservoir, and carrying the larger leg into the village requiring the supply, to act, with proper appliances, as a service main. This automatic mode of raising and delivering water has already been found available for towns as well as villages.

In the cases of Abingdon and Warwick, a siphon arrangement has been found very beneficial. The firm to which I belong, when devising the water supply for the former town (under the immediate supervision of Mr. C. F. Gower), adopted this expedient for raising the necessary supply for a population of over 6,000, which we had intended to obtain from a direct adit driven into the bed of coral rag, or calcareous grit, outcropping between Boars Hill and Abingdon; but which we abandoned in favor of a suggestion from Mr. J. Thornhill Harrison, of the Local Government Board, who, at an inquiry held by him, pointed out that the water bed which we were making preparations to tap might be considered a natural reservoir, from which the required supply could be raised by means of a siphon passing over the bank impounding the water. This object was effected by means of a 9 in. pipe capable of discharging 330 gallons a minute, laid from a reservoir holding 125,000 gallons (which it was found necessary to make within the calcareous grit for storage and ready discharge), the bottom of which was 40 feet higher than the highest part of Abingdon. The shorter leg of the siphon is about 9 feet in length, and reaches very nearly to the bottom of the reservoir. When the water, finding its way out of the calcareous grit into the reservoir, rises above the crown of the siphon (which it generally does during the night), the discharge is by gravitation independently of the siphon; but when it sinks below that level, then the siphon action is called into play. This arrangement has been in existence at Abingdon for four years, without any hitch or difficulty of any kind.

At Warwick, Mr. Edward Pritchard, C. E., adopted a somewhat similar contrivance, whereby he effected a very great saving in the cost of the works. It has now been in operation for more than eight years, and is stated by Mr. Pritchard to work satisfactorily. Siphons, whilst working automatically, involve very little outlay in maintenance, and they would be adopted much more frequently than they are at present, if their special nature and advantages were more fully understood. They have been used with great advantage for the drainage of land, and for the lowering of water

standing in bogs. I may mention, as an illustration, that in Scotland the Earl of Stair drained by this means a wet marsh near Culhorn-house, which had rendered that residence unhealthy. The siphon-pipe (seven inches in diameter) was half a mile long, and it has drawn down the water nine feet.

There is yet another means of obtaining water for villages, which it would be wrong to exclude from the consideration of sanitary authorities, as in some instances, we know from experience already gained, that it can be resorted to with advantage; I refer to the use of waters from cultivated surfaces, which the Rivers Pollution Commissioners have designated "suspicious" waters. To raise them above suspicion they should be collected and filtered through a bed of natural soil, extending to about one pole (of superficial area)per head of population. By this means the water would be made very superior to that consumed by the majority of householders in rural districts. The preparation of filter-beds of natural soil is simple enough. A plot of land, as porous and free in its subsoil as can be obtained, should be selected, and made suitable by special treatment, at such an elevation relatively to the land from which the water would be obtained, and to the village which it is intended to serve, as will receive the off-flow from the former on its surface, and allow it, after it has passed through the filter, to collect in a storage reservoir, and thence to reach the village at a serviceable height. The filter itself should be deeply underdrained, and the water to be filtered through it evenly distributed over its surface. No manure whatever should be applied in it.

The water of underdrainage, when found to contain ingredients of an objectionable character, which the analyses of Professor Way have shown may be the case, can be rendered perfectly unobjectionable by a second filtration through a plot of prepared soil, rigidly preserved from the application of manure.

When we are taught by chemists to believe that the extraordinary purifying powers of aerated soil will render innocuous the discharged sewage of towns in which exists organic nitrogen in considerable amount, we must be satisfied that, by a second passage through natural soil, the water of underdrainage, already once filtered, may be freed from any putrescible ingredients it may have once contained.

This expedient is only suggested where a village being in the neighborhood of an estate which the owner has underdrained, such owner will allow the water to be diverted from a natural stream, and filtered before it is supplied for domestic use.

I will close this short paper by drawing the attention of sanitary authorities in rural districts to the "Reservoirs Act, 1877," by which powers are given to the owners of land to supply water "to any sanitary or other local authority" by contract, and to charge their estates with the outlay on works.

Water Supply.

BY EDWARD EASTON, M. INST. C. E.

The object of this paper is to put before the conference, in as concise a form as possible, the considerations which should govern the supply of water for domestic and other purposes, not with the intention of enunciating any new thing, but with the hope of drawing attention to well-recognized principles which are too often forgotten or neglected.

The three chief points which have to be considered in relation to this subject are:

1. The source of the water.
2. Its distribution.
3. The conditions under which it is used.

1. With regard to the source, it is evident that, in designing a waterworks, the engineer has to provide that the water shall be adapted to the purposes for which it is intended. to be used, both as regards quality and quantity.

The question of quality will depend upon circumstances. It is essential, of course, that in every case the water shall be free from contamination by organic and other impurities; but the necessity of its being chemically free from other constituents will depend, to some extent, upon the purpose for which it will be used; for instance, in a manufacturing district, where the water is required for dyeing and such-like purposes, it must be free from certain mineral ingredients, whereas for the supply of

drinking water and for general purposes, this is a qualification which need not be insisted on.

It is now generally admitted that a soft water is preferable to a hard water, provided that the storage and distribution are properly carried out, and in every case where there is a choice of supplies, that which is soft, or which can be softened by simple means, should be chosen.

The process invented by Professor Clark for softening hard water by the deposition of a portion of the line, is of a very simple character, and it has been successfully adopted in many cases.

Sources of water, proper for use, may be classed under two distinct heads. 1st. Those which are afforded by nature in a state absolutely pure and fit for use, such as water drawn from wells and deep-seated springs. 2d. Those derived from water-courses or gathering grounds which are open to the atmosphere, and which must necessarily be exposed to the risk of contamination from external agencies.

In the case of the former, no works for storage or purification are necessary, the stratum of rock or other material from which the water springs, forming a natural reservoir and filter.

In the second case, it is necessary (*a*) that all direct pollutions shall be prevented from coming into the source; and (*b*) that in almost every instance, efficient means of filtration should be provided. The filtration ought, wherever it is found impossible to altogether prevent the chance of contamination, to include the use of some deodorizing agent, of which there exist more than one capable of practical application.

As instances may be mentioned the filtration at Wakefield, where, for many years, by the use of Spencer's magnetic carbide of iron, a water very much contaminated was rendered perfectly wholesome; and that at Antwerp, where Professor Bischof's spongy iron is employed with an equally good result.

2. Essential as it is to ensure that the source of supply is proper for the required purposes, it is equally essential that the mode of distribution shall be such as shall prevent its deterioration before being used.

To effect this, it is absolutely necessary that the reservoirs, into which the water is collected for distribution, should be covered, and that the mains and pipes should be perfectly air-tight, and laid at a proper depth below the surface, so as to preserve the water in its original state of purity, and, as much as possible, at the same temperature, during its passage from the source to the consumer.

One great cause of the complaints of the quality of the water in most large towns, is the use of cisterns for storing it in the houses, which it is impossible to employ without the risk of some injurious effect upon the water.

In the Session 1877–78, two bills were introduced into Parliament, at the instance of the Metropolitan Board of Works, for purchasing the undertakings of the London water companies, and for providing a separate supply of drinking water from the chalk. During the exhaustive examination of the waters supplied by the companies, made by the eminent gentleman who so fitly and ably occupies the chair, Sir Frederick Abel, assisted by Dr. Dupré, Mr. G. H. Ogston, Professor Voelcker, and the late able chemist of the Metropolitan Board, Mr. Keates, it was found that, whilst the water delivered in the mains was in almost every case excellent, the position and condition of the cisterns too frequently rendered it utterly unfit for human consumption. A great number of cistern deposits from all quarters of London were examined by these five gentlemen, with the general result just stated.

It is scarcely credible that the favorite place for fixing the cistern, from which the water for drinking and culinary purposes is drawn is immediately over the water-closet or next to the dust hole, whilst even in the better class of houses, where the cisterns are fixed in the roofs, they are very rarely sufficiently covered, and are open to contamination from soot, dust, inroads of black beetles, and other abominations. The latest researches of scientific men show that there is no more fruitful source of disease that such a condition of things affords. Although doubtless, a great deal has been done by the expansion of the system of constant service in London and elsewhere to remedy this frightful evil, the following extract from Sir F. Bolton's report for

the month of May shows that there is still much room for improvement. He says:

"In the monthly and annual reports on the metropolitan water supply, attention is drawn to the necessity which exists for a regular cleansing of cisterns, and also to the fact that contamination of water from gases generated by sewage is of far more frequent occurrence than is generally understood. Water pipes from cisterns are still to be found which are in direct communication with drains, so that gases may flow back into the cistern and become absorbed by the water. To prevent this an overflow pipe should be brought outside each house and the end left exposed to the air, instead of being carried into a drain, as is often the case. By the adoption of this plan poisonous effluvia and gases from drains will be got rid of, which would otherwise ascend through the pipe, and not only be partly absorbed by water in cisterns, but be mixed with the air in the houses, thereby becoming a cause of disease.

"The attention of consumers has been drawn to the fact that, in houses supplied on the constant system, all danger of drinking stale or contaminated water from cisterns may readily be avoided if the following recommendation is carried into practice, viz., to attach a small draw-off tap to the communication pipe which supplies the cistern from the main in the street, from which water may be drawn at any moment, day or night, direct from the works, thereby taking full advantage of any efforts made by the companies to purify the water to the utmost extent. This water should be used for drinking and cooking, and the contents of cisterns made use of for washing, flushing, baths, and similar purposes."

An abstract from these reports of the water examiner is printed by the companies at the back of the collectors' rate papers, so that no consumer of water can now be exonerated from the charge of negligence if this abuse is allowed to continue in his house.

3. This consideration naturally leads up to the third division of the subject, viz., the conditions under which water should be used. And first, it is essential that a constant supply should be given, without which it is difficult to avoid the deterioration of the water above alluded to.

Not only is it impossible to give an adequate supply by the intermittent system without having storage cisterns in the houses, but there is also a serious danger of contamination by the possible admission of foul air or gas into the mains when the water is turned off. There have been several instances of a water supply being seriously affected from this cause.

But to give constant service it is absolutely necessary, also, that the supply should be under proper regulations, which shall ensure the prevention of undue consumption and misuse of the water.

Not only are the difficulties of providing the supply greatly increased where waste is allowed to prevail, but the cost to the community is augmented without the slightest corresponding benefit to health.

Nothing is more fallacious than the idea, prevalent among a large section of consumers of water, that the allowing of taps and waterclosets to run to waste assists in the flushing and cleansing of the sewers, and therefore conduces to health. These continuous dribblings of water can have no effect whatever in removing any obstruction or accumulations which may exist in the large drains. The only proper and effectual way of removing fecal matter is so to regulate the use of water that it shall be proportionate to the work it has to do at the moment. Where this is done, by the use of properly constructed waterclosets, well-proportioned drains, and by keeping out from the system of sewers the rainfall on the streets and houses, the ordinary quantity supplied to a town is quite sufficient to perform this service without having recourse to extraordinary means. The question of dealing with the sewage of large communities, which is now so full of difficulty, would be much more easy of solution if these principles were more generally acted upon.

For these reasons, it is not desirable that the supply should be unlimited in quantity; on the contrary, every precaution should be taken to make that quantity commensurate with the real wants of the consumers.

It is quite certain that in almost every town a very large proportion of the water

delivered through the mains runs needlessly to waste.

To take an example on the largest scale, the quantity supplied to London, according to Colonel Sir F. Bolton's return for the month of May, amounts to 32 gals. per head per day, about 20 per cent, of which, or say 6 gals., it is estimated is used for other than domestic purposes, leaving 26 gallons per head as the quantity supposed to be absolutely consumed in the houses. Now it has been ascertained that, on the average, the water really required is not half this quantity; and there is also no doubt that, by taking proper precautions, the amount delivered can be made to approximate very nearly to the actual use.

At Liverpool, by means of careful inspection of fittings, aided by the use of Deacon's meter, a most ingenious arrangement, by which it is easy to localize, and therefore detect, waste, the consumption of water has been reduced from 33 to 22 gallons per head per day, and, within my own experience, the adoption of the same system has, in six or seven instances, produced even more satisfactory results.

The waste of water, whether it arises from leaky joints in the mains and service pipes, or from defective fittings inside the houses, can only be injurious to health from the increased humidity which is thereby imparted to the soil and atmosphere, and which, as is well known, contributes so much to the spread of infectious diseases and the establishment of epidemics.

At this moment, when we are suffering to a greater extent than usual from the contamination of the Thames, owing partly to the presence of a large quantity of sewage, but also to the abstraction of so large a proportion of the summer flow of the river, it is manifest that the reduction by 33 per cent. of the amount drawn from and discharged into the river would go far to ameliorate the condition of things now complained of.

Among the different proposals which have been made for the introduction of a system which would ensure the prevention of waste, is that of furnishing the supply by meter. This is open to the grave objection that, in order to save money, people would be tempted to go to the other extreme, and to content themselves with an insufficient quantity. To obviate this, some such arrangement as that proposed by the writer to the Select Committee of the House of Commons, over which Mr. Ayrton presided in 1867, might be effectual. The following extract from the evidence given before that committee will explain the proposal:

"I think a better method altogether might be devised of supplying the houses in London with water—a better system might be adopted to prevent waste. I should provide a constant service by meter, but under different conditions to any hitherto proposed. I think it could be designed with perfect fairness to the water companies and to the consumers, by making certain arrangements, and the general principle upon which I would propose that what should be done would be this: that there should be a sliding scale adapted to the class of house, each house should have a certain amount of water allotted to it. I would take a £100 house, and allot to it 150 gallons per day, and to a £200 house I would allot 300 gallons of water per day, and so on, upwards and downwards, provided that no house should have less than 50 gallons. Let the companies charge the same rate as they do now for that minimum quantity of water, and if more is consumed or passes through the meter the consumer would have to pay for that additional quantity."

Although at first sight the expense of the meters would appear to be prohibitive, both the consumer and supplier would soon be reconciled to the outlay, the one because he would know what he was paying in proportion to the water he received, and the other because they were only supplying water for which they were paid.

The consideration of the subject of this paper would not be complete without a reference to the important question of the conservancy of our rivers.

It is useless to discuss the method and conditions of supply, if the sources of water are not to be preserved to us, and it is quite certain that, with the immense growth of the population of this kingdom, it will not be long before this preservation becomes a pressing necessity.

In the report presented to Parliament by the Duke of Richmond's Select Committee on Conservancy Boards, in 1877, a very workable scheme was recommended by their Lordships. The Committee say that:

"In order to secure uniformity and completeness of action, each catchment area should, as a general rule, be placed under a single body of Conservators, who should be responsible for maintaining the river, from its source to its outfall, in an efficient state. With regard, however, to tributary streams, the care of these might be entrusted to district committees, acting under the general directions of the conservators; but near the point of junction with the principal stream they should be under the direct management of the conservators of the main channel, who should be a representative body, constituted of residents and owners of property within the whole area of the watershed."

But although the question of improving the water supply, by preventing the pollution of the rivers, was incidentally mentioned by their Lordships, it is evident that the main object of the report was the prevention of floods, and not the conservancy of water for the supply of populations. Now, it may well be said that the one subject is at least as important as the other, and just as the recurrence of a number of wet seasons at that time brought the question of the floods prominently before the Duke of Richmond's Committee, it may safely be asserted that a corresponding succession of dry seasons will compel the serious attention of the Government to the other part of the subject. We need go no further than our metropolis for the proof of this, for if, in addition to the saving of water by the prevention of waste, the flow of the Thames were properly regulated by works in the higher parts of its watershed, there is no reason why the river should not be in a condition which, although leaving very much to be desired in the way of improvement, would yet be tolerable, and, according to past experience, absolutely not injurious to health.

When presiding over the Mechanical Section of the meeting of the British Association, at Dublin, in 1878, on which occasion the opportunity was taken to very fully discuss, from a variety of aspects, this question of rivers conservancy, I made a suggestion which, I believe, is worth repeating at the present time. In my address to the Section it was stated:

"When it is considered that many lives are annually sacrificed, either directly by the action of floods, or by the indirect but no less fatal influence of imperfect drainage—when it is remembered that a heavy flood, such as that of last year, or that of the summer of 1875, entails a monetary loss of several millions sterling in the three kingdoms; that during every year a quantity of water flows to waste, representing an available motive power worth certainly not less than some hundreds of thousands of pounds; that there is a constant annual expenditure of enormous amounts for removing *débris* from navigable channels, the accumulation of which could be mainly if not entirely prevented; that the supply of food to our rapidly growing population, dependent as it is at present upon sources outside the country, would be enormously increased by an adequate protection of the fisheries; that the same supply would be further greatly increased by the extra production of the land, when increased facilities for drainage are afforded; that, above all, the problem of our national water supply, to which public attention has of late been drawn by H.R.H. the Prince of Wales, requires for its solution investigations of the widest possible nature, I believe it will be allowed that the question, as a whole, of the management of rivers is of sufficient importance to make it worthy of being dealt with by new laws to be framed in its exclusive behalf.

"A new department should be created—one not only endowed with powers analogous to those of the Local Government Board, but charged with the duty of collecting and digesting for use, all the facts and knowledge necessary for a due comprehension and satisfactory dealing with every river-basin or watershed area in the United Kingdom—a department which should be presided over, if not by a Cabinet Minister, at all events by a member of the Government who can be appealed to in Parliament."

It is earnestly to be hoped that no further time will be lost in passing an Act to deal with this subject, and that no

considerations of a party or private nature will be allowed to prevent a scheme of so important and imperial a character being made as complete and comprehensive as possible.

In conclusion, as I commenced by saying, I have not attempted to say anything new; indeed the subject has already been in the hands of far abler exponents than myself; especially would I refer to Dr. Frankland's very able and comprehensive Sixth Report of the Rivers Pollution Commission, the careful study of which is recommended to everybody who wishes to master the details of the question.

SPONTANEOUS COMBUSTION IN COLLIERIES.*

By —. DURAND.

From Selected Papers of the Institution of Civil Engineers.

Causes.—The primary causes of fires breaking out in collieries where the coal is contaminated with pyrites are believed by the author, who is engineer of the Doyet Collieries,† in the department of Alier, France, to be the three following: Oxidation of pyrites, friction from slippings, and warmth of air current. Experiments made by Mr. Fayol have shown that above ground a heap of Commentry small coal, presenting to the air a surface of not more than about $1\frac{3}{4}$ square yard per cubic yard, will, if once it gets heated to a temperature that lies somewhere between 140° and 212° Fahrenheit, go on heating more and more till at length it takes fire.

Pyrite met with in coal-seams is either amorphous or crystalline, and occurs in the shape of nodules, flakes, bunches or veins, while sometimes it is so finely disseminated throughout the coal as to be invisible. In dry air and at low temperatures it does not oxidize; but its dissemination through coal or shale gives it a more porous character than appertains to it by itself, and in almost all cases it oxidizes in moist air and becomes converted into sulphate of iron, the excess of sulphur being set free. The heat developed by the oxidation is further augmented, where there is sufficient moisture present, by the subsequent conversion of the sulphate of iron into hyposulphate, with liberation of sulphuric acid, which, when mixed with one-quarter its weight of water, rises to the temperature of 220° Fahrenheit. Various other chemical actions also conduce to the development of heat; while there is no absorption of heat by the formation of any gas during the oxidation of the pyrites. At Doyet Collieries the roof over the thick seam of coal is composed in some places of fine shaly sandstone containing pyrites; and near the outcrop, where cracks have occurred in the roof, the moisture from the surface and the air from the mine, penetrating into them, have caused the roof to get red hot, and to set fire sometimes to the timber props. A mere bunch of pyrites, however small, occurring either in the coal itself or in a shale parting, is quite sufficient to serve as a lucifer match for starting a conflagration. The sulphur liberated by decomposition of pyrites burns at 480° Fahrenheit, and any sulpho-carbons which may also be formed burn at about 660° Fahrenheit; whilst the hydro-carbons of coal will not burn below 930° Fahrenheit at least. Hence pyrites, as furnishing the most inflammable products, are really what give the start to a fire.

Where pillars of coal become cracked and crushed under the pressure of the roof, slippings occur, producing considerable friction, which develops corresponding heat; and, as the surfaces sliding past each other are uneven, the friction and heat are concentrated upon the prominences in contact. The heat thus becomes sufficient not merely to accelerate the action of pyrites, but possibly to ignite coal seemingly free from

* The original article appeared in "Bulletin de la Société de l'Industrie Minérale," 1883, vol. xii., pp. 43-89.

† It will be borne in mind that in many of the collieries in the Midland and other coalfields of France the seams are not only of great thickness, sometimes even more than 20 yards, but are also inclined at steep angles, sometimes nearly vertical.—A.B.

pyrites, even anthracite hard to burn. In the open working at the outcrop at Doyet the coal has been set on fire by a sudden slip of the ground above.

An air current that was warmed by uncondensed steam discharged from an underground engine at Doyet caused a little small coal, which had accumulated against some timbering, to get so hot that the timber took fire after the engine had been at work rather more than three months. In return air-drifts the crushed coal in the roof is particularly liable to heat under the influence of the warm and moist current.

In seams free from pyrites the author believes oxidation of the hydro-carbons on exposure to air cannot develop heat enough to ignite the coal, and the only way in which he can account for spontaneous combustion in such coal is by the presence of dust or fine slack in the midst of any heaps that are found to be heating. Dust and fine slack he considers capable of exerting a condensing power upon the combustible gases that are ready to escape from bituminous or gaseous coal, and also upon the oxygen of the air; and the heat so developed may become sufficient to fire the gas, and thereby the coal.

While, therefore, spontaneous combustion may occur in any colliery, whether the coal contain pyrites or not, it is more particularly in seams of caking coal, containing pyrites that, as the workings progress, the pillars left standing grow hot rapidly, under the combined action of oxidation of pyrites, pressure and subsidence of roof, and oxidation of hydro-carbons through condensing power of dust. It is the pyrites, however, which, wherever present in any appreciable quantity, play the principal part in starting ignition, and thus constitute the primary cause of fire; the other causes are then but secondary, although they may so far supplement the start thus given as to make a seam containing but little pyrites appear readier to fire than one containing much more.

Development.—The development of spontaneous combustion is considered by the author firstly in the case of masses of coal, such as pillars left in working. Really solid pillars never fire; those that do are always fissured with numerous cracks, and are more or less crushed. Outbreaks of fire are encouraged by the presence of any coal crushed small, which, in its finely subdivided state, promotes the chemical actions that induce heating. Fire first smoulders at the bottom of the innumerable cracks by which the pillars have become fissured under the crushing load they have to support; then the walls of the cracks get red hot and burn, sometimes bursting suddenly into flame where the previous heating has covered them with bituminous matter. The tarry smell thus occasioned often betrays the existence of fire before it has become visible; and so difficult is it to find its actual seat, that often it is not discovered until it has crept outward towards the air current at the mouth of the chinks, and has ignited the crushed coal behind the timbering of the roads, and then the timbering itself. The danger is augmented wherever there are timbered excavations overhead; and still more wherever a timber drift has been pushed forward under a mass of crushed coal overhead. Through such a mass air circulates easily, heat and moisture collect there, and fire breaks out quicker than where the overhead coal has been got out previously.

Wherever crushed coal can be harbored on or amongst the rubbish that is packed into the goaf, fire is sure sooner or later to break out. It begins at some distance in from the roads, and creeps out gradually towards them, igniting on the way any timber that may have been left buried in the gob-packing; the pungent wood smoke gives immediate warning of the fire.

Pillars purposely left unworked, either for maintaining a shaft or because the coal in them is not good enough, are also liable to take fire. The road bears unevenly around them, they crush and crack under it, and small crushed coal accumulates next to the gob-packing; the heavier the pressure the sooner do the pillars heat and fire. Similar circumstances occur where a nip in the seam stops the getting of coal.

Where the goaf is not packed with rubbish, but the ground is left to fall in, there is certain to be fire if any crushed coal is left behind. The danger is liable to be enhanced by accumulation of explosive gas in the large cavities; as is the case also wherever cavities result from

settlement of rubbish packed in the goaf.

As to collieries being set on fire from a lamp or an explosion of fire-damp, the author considers this can only occur where the mass so ignited has got very hot beforehand, and is ready to catch fire in a moment. An explosion, moreover, throws down a lot of coal that will easily take fire, besides shaking and splitting the pillars, and so rendering them more ready to ignite.

Hard seams of caking coal, containing much gas and pyrites, are the most liable to spontaneous combustion. In very fiery seams the author has noticed that heating occurs generally in the dampest places, or along return air-ways when the air is warm and moist. Where a pillar of bad coal had stood without heating for seven years at the foot of an incline in a current of fresh air from the downcast shaft, an alteration in the ventilation exposed it to the return current of warm moist air, and it then got so hot in two months as to necessitate its speedy removal; by the time it could be worked, it was already too hot to touch in some places.

The nature of the roof tells variably. In some collieries fire is found to break out more readily under a roof of tender shale than under one of thick, hard sandstone. At Doyet, on the contrary, the thick sandstone roof, settling unevenly after the workings, leaves roof cavities, in which air circulates and encourages heating; while in places where a ceiling of shale separates the coal from the thick sandstone, the shale falls, and no dangerous cavities are left.

Coal or rubbish tipped in heaps above ground from the pit mouth is liable to heat and fire by oxidation under the action of the air and wet, wherever the smaller stuff that collects at the top of the heap is combustible enough. The fire breaks out first a little below the top, on the side most exposed to the wind; and spreads thence throughout the entire tip. It is sometimes started direct from the braziers burning at the pit-mouth to light the landing of the cages; the tip then ignites first at the top, whence the fire spreads downwards and laterally.

Prevention.—If the coal in a seam could only be preserved from getting crushed and fissured by increased pressure in working, or at any rate if all access of air could be cut off from it when so injured, its spontaneous combustion would be prevented. In the rare cases of quarrying an outcrop, the coal, as long as the over burden can be removed, can be worked in successive courses or steps from the top of the seam downwards, and can thus be got whole throughout the entire thickness of the seam. If the over burden be sent down the pit to serve as rubbish for packing the goaf in underground workings progressing simultaneously, the open-air working can be continued to a somewhat greater depth: at the risk, however, of finding that the deeper coal so reached has been already injured by settlement due to the underground operations.

When coal is got underground in successive courses or steps, one below another from the top downwards, no packing in the goaf, not even were it masonry, will entirely prevent settlement of the superincumbent mass, whereby the coal in the lower and later-worked steps is always more or less crushed. A partial remedy consists either in packing with rubbish of a clayey nature, which consolidates into a more compact mass; or in leaving a sufficient thickness of coal underneath the packing of the goaf in the topmost course, and afterwards getting out as much as possible of this thickness, by working backwards below it and packing the goaf of the lower working also; or again, in timbering the floor of each course so thoroughly as to form a roof for the subsequent working of the next course below. But these methods, besides being costly and yielding a low output with a large proportion of small coal, are not always successful in obviating spontaneous combustion; still less so when the goaf is not packed at all, but is left to fall in.

What has to be guarded against is an actual outbreak of fire; so long as the coal is merely heating, the small quantity of noxious gas given off hardly matters, and the only drawback is that the workings sometimes get inconveniently hot for the men. The longer all risk of firing can be staved off, the more possible will it be to adopt the mode of working that will yield the largest output at the lowest cost, namely, in seams inclined at steep

angles, by laying out the workings in successive stages or panels of great height (measured up the slope), which entails less expense for the preparatory operations of laying them open; several of these stages are then worked simultaneously, the getting of the coal being proceeded with in each stage from the bottom upwards, by a succession of horizontal courses or excavations. By this method the bottom courses in each panel feel the roof-pressure least, and yield a great quantity of large coal, which is won without difficulty, and with less risk of heating and firing. But in the uppermost courses the coal gets more or less crushed by the augmented pressure; hence, to avoid fire there must be some limit to the total height of each panel, or rather to the number of courses contained in it, the bottom courses being of greater height than the upper. In a thick and well stratified seam of strong coal, containing not many partings, and inclined between 14° and 30° to the horizon, the total height of each panel may be 26 yards, measured up the slope, and the height of the bottom course 8 yards. But in the main seam at Doyet, which, though hard, is of variable quality and too liable to fire, the height of the courses is only that of a singe tier of timber props, say 2 to 3 yards. Here four courses can be got, and a fifth started, without any fire having broken out; only no course must take more than six months in getting, and all the goaf must be thoroughly filled in. Quick getting is indispensable for avoiding fire in seams that fire readily. Usually by the time the fifth course is reached, the broken coal it contains is already hot, and great care is needed to prevent its burning whilst getting; hence five courses would seem to be the general limit for the height of a panel. As soon as the third course from the bottom is being got in any panel, the getting can be started of the bottom course in the next panel below; if the working of the lower panel were begun sooner, that of the upper would be endangered by settlements.

Alike in laying out the roads and in getting the coal, care must be taken to avoid the formation of roof cavities, from which start cracks that radiate through the seam; such cavities are most liable to occur at junctions of roads, and are to be guarded against by careful timbering, which must be well watched. Large cavities occurring in spite of these precautions should be cleared out, and then thoroughly filled in with good packing of small rubbish brought from above ground. Where gob roads have to be kept open for working or ventilation, they should either be shifted so as not to run through the middle of the goaf, but along its margin; or else they should be walled thick enough with good packing impervious to air and moisture, particularly when used as airways. They should be kept at a safe distance from any crushed pillars that have been abandoned in working.

The advantages of packing the goaf with rubbish are, that the workings are thereby kept cooler, settlements are less expansive, pillars get less crushed, and are therefore less liable to heating, and fewer dangerous roof cavities occur in which an outbreak of fire would be difficult to extinguish. In packing composed of friable stuff, the smaller bits fill up the spaces between the larger; and, if of a somewhat clayey consistency, the whole compacts under the load into a solid mass impervious to air. Good packing of this kind should always be used in the bottom courses of each panel; then by the time the top course is reached in the next panel below, the coal will there be got under a roof as compact as solid sandstone.

Spoil got from stone-drifts should not be used for packing the goaf; the large blocks of stone are too hard to crush under any settlement overhead, and air can pass too freely amongst them. In working a panel where the bottom course had been wholly packed with spoil got from sinking a shaft and from driving stone-drifts, notwithstanding that the spoil itself was incapable of heating, the author found that pillars of considerable size, which had been left behind in the midst of this spoil because not worth getting, grew hot so rapidly as to be taking fire by the time the second course was finished and the third begun. It was only by then surrounding this dangerous goaf with small rubbish carefully rammed in, that the winning of the coal could be finished to the top of the panel. Some years later, when the working of

the next panel below came in under the same place, similar trouble from heating had to be encountered. Hence the author regards any spoil got underground as so bad for packing the goaf, that it should never be used unless the precautions are taken to pick out of it all stuff that could burn, and even then to keep it clear of contact with any masses that can heat. It is indeed by no means a dead loss to send up all such spoil to bank and throw it over the tips, where after two or three years' exposure to the atmosphere it may, if meanwhile prevented from burning, become good enough to send down again into the pit for use as packing.

The best packing of all consists of loamy earth, and surface strata more or less disintegrated; the former is necessary wherever access of air has to be stopped at once without waiting for the roof to settle down heavily upon the packing. Where the goaf is well packed with good stuff, the timbers, whether upright props or roof slabs, can be left behind to become crushed by the load and buried in the packing; otherwise they should be removed, even if only partially, as a precaution against fire. By way of rendering the rubbish tips at the surface sooner ready for use as packing, it is sometimes thought desirable to let them burn as freely as may be. But this opinion is not shared by the author, who considers that not only will a tip take a very long time to burn through to the middle, but that, after the fire has all burnt itself out, the ashy stuff will be too light, too dusty, too hot, and not binding enough, to be suitable for sending underground. Nevertheless even such burnt rubbish is preferable to spoil got underground and packed there at once.

Ventilation by a forced current of air under pressure has been found by the author to be favorable to spontaneous combustion. Whether compression or exhaustion be employed, the greater the difference of pressure between the entering and the return air-currents, the more readily will the air penetrate cracked and crushed coal, and thereby promote heating and firing. In this respect, sharp turnings or narrowing of roads, and air-doors situated in a strong current, in the midst of crushed pillars or badly packed rubbish, are sources of danger, as are also inclines rising steep, and upcast pits. Hence, wherever an inlet air-way runs at all near a return air-way, the intervening pillars or ribs of seemingly solid coal require specially careful watching.

The coolness of the air current is practically of no value for preventing, though it may somewhat retard, the heating of cracked pillars, or of broken coal that has fallen from roof cavities or elsewhere. In a colliery where an old drift $4\frac{1}{2}$ yards long, from a shaft to an inlet air-way, had been closed with rubbish carefully packed, the subsequent settlement of the packing had left a space above, into which a little crushed coal had fallen from the roof; the coolness of the ingoing air did not prevent this slack from heating and beginning to burn; and it had to be all cleared out, and earth rammed in its place.

A return air-current should never have to go downhill, otherwise it accumulates heat and moisture at the upper end of the descent, thereby favoring spontaneous combustion at that place. Where distant workings are liable to be insufficiently ventilated, owing to negligence in maintaining former roads, now used as air-ways only, fresh air should be supplied direct to them, either by splitting the main ingoing current, or by sinking a new shaft from the surface. It is better to split the air than to course a single current through too great a length, because the latter means greater difference of pressure, attained with more risk of fire.

At the Doyet collieries, wherever the seam is not thick enough to work by the foregoing method of horizontal courses, and where the expense of laying out the workings on that method would be too great, the plan is followed of getting the coal in inclined courses, that is by pushing the working faces forwards uphill along the slope of the seam, instead of horizontally along its strike. The uphill courses however are more difficult to keep open, and are liable to worse falls; each course takes longer to get, so that the surrounding crushed coal runs greater risk of heating. And this risk is further enhanced by the augmented draught consequent upon the air-current passing up the slope from the lower to

the upper end of the course; hence, fire breaks out more readily, while it is also more difficult to contend with on the slope than in horizontal workings. On the other hand, the rather larger quantity of packing used in uphill than in horizontal courses is an advantage against fire.

Firing of slack-heaps above ground can be effectually obviated, in the author's opinion, only by completely precluding all penetration of air into them. To ventilate them, with the idea of keeping them cool, he considers as ineffectual and as dangerous as to let air penetrate crushed coal in the pit. From experience of its success in smothering fires on the sloping banks of out-crop workings, he recommends the expedient of covering the slack-heaps with a layer of refuse slimes from the coal-washers. such a covering, being coaly and not clayey, does not set hard and crack, but follows readily any subsidence of the stuff beneath it. A layer 12 inches thick he believes would be an ample protection against firing, or even heating; and he suggests that on shipboard spontaneous combustion in coal cargoes might be altogether obviated by a layer 6 inches thick, the coal being so stowed as to prevent the covering of slimes from disappearing into the interstices. To prevent spoil-tips from firing, the stuff should be tipped in a layer too thin to heat under the action of the air; and should be left long enough exposed, before tipping the next layer over it; if it be also freed beforehand from all that can be utilized, so much the better coal.

THE BAROMETER AND THE WEATHER.

ABSTRACT OF A MANUAL ISSUED BY THE AUTHORITY OF THE METEOROLOGICAL COUNCIL.

From the "Nautical Magazine."

The Atlantic Ocean will supply types of the winds usually met with in other seas. An area of high pressure occurs in the North Atlantic between the parallels of 30° and 40° north, and according to Buys Ballot's law, the wind draws round it, being northerly on its eastern, easterly on its southern, southerly on its western, and westerly on its northern side.

A seaman, therefore, outward bound from England, say, to the Cape of Good Hope, passes from the north-east to the east and south-east side of an area of high pressure lying to the westward of him, and as he approaches the coast of Portugal, the wind very generally comes from north-west, gradually shifting to north and north-east as he proceeds to the southward.

On the other hand, when a homeward-bound ship approaches the northern verge of the N. E. Trades, she finds that the wind draws to the eastward, with a rising barometer. As the area of highest pressure is reached the barometer ceases to rise, and the wind dies away. These are the dreaded "calms," or, as Maury calls them, "Doldrums of Cancer." There being no difference of pressure there is no wind, and these calms coincide with a large area of high and even pressure, where a ship will experience little or no wind until she has crept to a part of the sea where the pressure commences to decrease.

If, as occasionally happens, it is found that the N. E. Trade gradually turns into a S. E., S., and S. W. wind, it will be understood, from what has already been said, that a vessel experiencing these changes has passed round the S. W., W., and N.W. sides of this area of high pressure, thereby avoiding the region of calms altogether.

There is a similar area of high pressure in the South Atlantic, with a corresponding circulation of the wind round it.

The homeward-bound ship, after rounding the Cape of Good Hope, is at the polar edge of the S. E. Trade on the eastern side of the South Atlantic, just as the outward-bound ship is at the polar edge of the N. E. Trade when off the coast of Portugal, and the first wind she

experiences is from S. W., changing to S. and S. E. as she proceeds to the northward, which (according to Buys Ballot's law, when applied to the southern hemisphere), shows that she has passed along the S. E., E., and N. E. sides of an area of high pressure.

Again, the outward-bound ship, as she draws towards the southern verge of the S. E. Trades on the western side of the South Atlantic, very generally experiences changes of wind to N. E., N., and N. W., which are the winds met with in the southern hemisphere on the N. W., W., and S. W. sides of an area of high pressure, corresponding to the winds already noticed as being experienced on the western side of the North Atlantic.

Areas of high barometrical pressure occur in many other parts of the ocean, similar to those of the Atlantic, and corresponding winds circulate round them.

CYCLONIC GALES OF THE TEMPERATE ZONES.

The great currents of the atmosphere, which give rise to the prevailing winds, are thus seen to be regulated by the positions of the permanent areas of high and low pressure, and in these currents, subsidiary areas of low pressure make their appearance, and are carried along with them, and these traveling areas frequently give rise to gales.

In the temperate zone of the North Atlantic these gales, which almost invariably travel to the eastward with the prevailing atmospheric current from the west, generally commence at S. and end at W. or N. W., with little or no E. wind. The probable reason of this is that the areas of low pressure to which they are related have steep gradients only on their E., S. E., S., and S. W. sides, there being little or no difference of pressure between their center and the more permanent depression which lies to the north of them.

The ordinary gales of high southern latitudes are similar in character to those of the northern hemisphere. They also accompany areas of low pressure traveling to the eastward, and considering that an equatorial wind is here north instead of south, the winds are similar, for they commence at N., and end at W. or S. W., with little or no easterly wind, probably because the pressure to the S. is so much lower than that to the N. of the tract in which they occur.

The cyclonic storms of the Temperate Zones do not often present the phenomena of a central calm, with the winds blowing from nearly opposite directions on each side of it. There is, therefore, not so much risk of being taken aback as in the tropical cyclones; but it is advisable for a captain to know on which tack it will be safest to lie-to if obliged to do so, and this will be the same as that for the cyclones of the respective hemispheres.

The most serious sudden shift of wind which is to be expected in these storms is that from south-west to north-west in the northern hemisphere, or from north-west to south-west in the southern. This is generally accompanied by heavy rain or hail, with thunder and lightning, while the temperature falls several degrees with the first blast of north-west or south-west wind, as the case may be, according to the hemisphere.

In considering how to act in such circumstances, there are two matters to which the seaman's attention should be directed, as they seriously affect the conclusions he should draw from his barometer readings.

The first is that on the one tack his barometer has a tendency to rise, on the other it has a tendency to fall. The tack of rising barometer is the starboard in the northern, the port in the southern hemisphere. This may be explained as follows:—

According to Buys Ballot's Law in the northern hemisphere the lower barometer is on your left when your back is turned to the wind, and as when you are thus placed a ship on the starboard-tack is advancing towards your right, she goes towards the higher barometer and recedes from the lower. In the southern hemisphere this is reversed, and the ship on the port-tack advances towards the higher and leaves the lower barometer.

But this rule will only be strictly applicable so long as no change takes place in the barometric pressure, and it may so happen that a high pressure towards which the ship is going may be receding from her faster than she sails, and a lower pressure may be coming up astern and overtaking her; or it may be that a lower pressure towards which the ship is sailing may be moving away faster than she sails. Still the influence of the tack must

always be felt, and on the whole it may be said that in the northern hemisphere, a rising barometer on the starboard-tack is not sufficient indication of improving weather, and other signs should be looked for before trusting it. In all cases for the northern hemisphere a rising barometer on the port-tack is a valuable indication of improving weather, while a falling barometer on the starboard-tack is an important warning in the other direction. This order is reversed in the southern hemisphere.

The second point to consider is the relation which the course and the speed of the ship bear to the tracks and progress of the areas of low barometric pressure and their corresponding wind-systems, in parts of the sea where the general tracks of storms are known. This will be easily done by taking, as an illustration, the case of a steamer traversing the North Atlantic between England and America, where storms generally move in an easterly direction.

If a storm is advancing eastwards at the rate of, say, twenty miles an hour, and if the ship is steaming at the average rate of, say, ten miles an hour, the result will be that when going westward the ship will have a relative rate of motion towards the storm of thirty miles an hour, but when going eastward, of only ten miles an hour.

In other words, ships when outward bound across the Atlantic meet the advancing storm systems, which commonly travel from west to east, and when homeward bound run with them, consequently the rapidity with which the barometer falls or rises and the wind shifts is proportionately greater in the former case than in the latter.

GALES OF THE NORTH TEMPERATE ZONE.

The ordinary gales of the north Temperate Zone commence at S. E. or S. and end at W. or N. W. If a ship in these latitudes experiences a fresh S. or S. E. wind, with a relatively high temperature and falling barometer, Buys Ballot's law shows that there is an area of low pressure to the W. or S. W. of her; and it is probably traveling to the E. or N. E. Experience shows that whether the ship be hove-to or stands to the westward, the barometer will fall until the wind shifts to the westward (which generally happens during a heavy shower of rain, together with a sudden fall of temperature), when the barometer will probably rise as fast as it previously fell, and a strong N. W. wind will set in.

From what has been said it will be clear to the navigator that in northern latitudes, at the setting in of a southerly wind, a sailing ship as well as a steamer bound to the westward will, by her course and speed, cause the barometer to fall quicker than if she hove-to or stood to the eastward, so that in this case also the state of the sea and other appearances ought to be considered, or her captain may be led to anticipate worse weather than is really coming.

With a southerly wind and falling barometer, a ship bound to the westward might gain by running to the northward with the object of causing the wind to back to the eastward, but the type of gale in which this is possible resembles a cyclone, and does not represent the ordinary gales of these latitudes which begin at S. and end at W. or N. W. Again, it might be possible for a ship, with the first of the southerly wind which exists on the east side of the area of low pressure, to get less wind by running to the north, but as the extent in latitude of the cyclone area is not known, and as there is no certainty that she would get into more moderate weather by doing so, she might do herself more harm than good.

It seems, then, probable that a ship bound to the southward or westward must face one of these gales if she meets it. A weak ship, whose object is to stem the sea and get safely through, without considering progress, should lie-to on the starboard-tack, as the wind generally shifts from S. to S.W., W. and N.W. This would of course be the best plan for any ship which found the gale too heavy for her. But a well-conditioned ship, bound to the westward, may keep on the port-tack until the wind shifts to west with a rising barometer, and then tack to the south-westward. This plan would, of course, tend to bring her into the trough of the sea, and she would be more likely to be caught aback as the wind changed, but we are assuming that her captain will be prepared to meet these risks.

When the wind has shifted to N.W. the starboard-tack takes her away from

the center of such a disturbance, though she may soon sail into the southerly wind of the eastern side of another low-pressure-area coming toward her. This would be a very common occurrence in winter.

GALES OF THE SOUTH TEMPERATE ZONE.

The prevailing gales of high southern latitudes resemble those of northern, and in describing them it is only requisite to remember that *there* north and south change places. For instance, as a ship bound to Australia gets into 40° S., "the Roaring Forties,"she experiences a series of gales which, commencing at N. or N.E., end at W. or S.W. Now with a northerly wind in the southern hemisphere there is a low pressure to the westward, and the way in which the wind usually changes proves that those areas of low pressure are also traveling to the eastward. Ships which keep a steady westerly wind for days, as they run to the eastward in high southern latitudes, are probably keeping company with one of these areas of low pressure, and if they had hove-to or commenced beating to the westward they also would have experienced many changes, just in the same manner as our steamers bound *to* America do, whilst those *from* America frequently keep a steady barometer and westerly wind for days. This receives abundant confirmation from the frequency of the barometrical oscillations and changes of wind, experienced by ships bound to the westward, in rounding either the Cape of Good Hope or Cape Horn.

The best method for dealing with a heavy gale, or with a weak ship in an ordinary gale, is reversed for high southern latitudes; there the port is the "coming up" tack, which enables her to stem the sea, as the wind usually shifts from N. by N.W. to S.W., and the port-tack with a S.W. wind takes her away from the low pressure to which the wind is related, though of course it may, and in the winter months most probably will, soon take her into the northerly wind of the eastern side of another low pressure coming towards her.

For a ship beating to the westward, of course the best progress is made by keeping on the starboard-tack with the wind N. and N.W. until it shifts to W. and S.W., when she ought to tack to the north-westward; but it will be seen that, as in the best method for making progress to the westward in high northern latitudes, the ship will be headed off, and get into the trough of the sea; she will also be more liable to be taken aback, as the wind changes, than if she were on the port-tack.

TROPICAL STORMS.

HURRICANES, TYPHOONS, OR CYCLONES OF TROPICAL SEAS.

Of all atmospheric disturbances, of the approach of which the barometer can supply indications, and the dangers of which it may enable the seaman to avoid, by giving him warning of their proximity and position, the most serious are the revolving storms of the tropics.

These storms, all of which may be properly termed cyclones, occur in the three great oceans, the Atlantic, Pacific, and Indian Oceans; but they are seldom experienced within 5° or 6° of the Equator, and have not been traced into very high latitudes. They appear to be most frequent and most severe in the West Indies, in the vicinity of Mauritius, in the Bay of Bengal, and in the China Seas; and in these seas they are most prevalent during the months following the summer solstice, or in other words, from July to October, in the northern hemisphere, and in the southern from December to April. In the Arabian Sea and in the Bay of Bengal cyclones occur most frequently from April to June, and in October, November, and the beginning of December.*

* TABLE OF RECORDED HURRICANES, CYCLONES AND TYPHOONS, IN VARIOUS PARTS OF THE WORLD.

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
West Indies, 300 years.........	5	7	11	6	5	10	42	96	80	69	17	7	355
South Indian Ocean (39 years, 1809 to 1848)................	9	13	10	8	4	—	—	—	1	1	4	3	53
Bombay, 25 years..	1	1	1	5	9	2	4	5	8	12	9	5	62
Bay of Bengal, 139 years.......	2	—	2	9	21	10	3	4	6	31	18	9	115
China Sea, 85 years............	5	1	5	5	11	10	22	40	58	35	16	6	214

They are commonly known as hurricanes in the West Indies; cyclones in the Indian Ocean; and typhoons in the China Seas.

The space over which these storms have been known to expand themselves varies from twenty or thirty miles to some hundreds of miles in diameter; the wind blowing with an ever varying force, now lulling into little more than a strong breeze, and as the center is approached often rising into a blast of irresistable fury.

It is an invariable characteristic of their revolution, that the gyration of the storm field takes place in one direction; in the northern hemisphere in the opposite direction to the hands of a watch, and in the southern hemisphere with the hands of a watch. The knowledge of this law is the more important, as it not only supplies the seaman with direct means of distinguishing these storms from gales in which the direction of the wind varies little if at all, but it reveals to him the position of the center or vortex with respect to the place of his vessel, and therefore points out the way to avoid it, and so to escape from the region of greatest danger, where the fury of the wind is most extreme, the changes of its direction most sudden and the sea most to be dreaded.

In the Atlantic and South Indian Ocean these storms commence to the eastward; for some days they travel along a path not exactly west, but inclining a point or two towards the pole of that hemisphere which they are crossing; and as they advance they seem more inclined to curve away from the equator. When they reach the 25th degree of latitude, they generally curve still more, until they move to the N. E. in the northern hemisphere, and to the S. E. in the southern hemisphere. The Atlantic storms almost always wheel round to the northward in the Mexican Gulf, or in its vicinity, and follow the sea-board of North America.

The cyclones of the Bay of Bengal appear to originate near the Andaman Islands, those of the Arabian Sea near the Lacadives. These generally travel to the westward and north-westward, the former sometimes crossing the Indian Peninsula, sometimes passing off over Bengal, and curving back to the eastward. The typhoons of the China Seas commonly take a westerly or north-westerly course.

The rate of movement of these storms, though variable, may be averaged at 300 miles a day in the West Indies; in the Arabian Sea, in the Bay of Bengal, and in the China Sea, 200 miles a day; whilst in the Southern Indian Ocean their rates vary from fifty to 200 miles a day.

The indications of the approach of a revolving storm are the usual ugly and threatening appearance of the weather which forebodes most storms, and the increasing number and severity of the gusts with the rising of the wind. These signs are in some cases preceded by a long heavy swell, and confused sea, which comes from the direction in which the storm is approaching, and travels more rapidly than the storm center.

The best and surest of all warnings, however, will be found in the barometer. In every case there is great barometric disturbance, the barometer at the centers of some of the storms standing fully two inches lower than outside the storm field. Accordingly if the barometer falls rapidly, or even if the regularity of its diurnal variation be interrupted, danger may be apprehended.

The first care of a master of a vessel caught in a cyclone will be to find how the center bears from him. In the northern hemisphere let him, facing the wind, take eight points to the right of the direction of the wind, and that will be the approximate bearing of the center; in the southern hemisphere take eight points to the left. Thus, in the northern hemisphere with the wind from N. E., the center will bear S. E., and in the southern hemisphere with the wind from N.W., the center will bear S.W.

In the present discussion, the motion of the wind in a cyclone will, for the sake of simplicity, be treated as approximately circular. But this is not strictly the case, and there is evidence to show that frequently in some parts of the storm-field there is more or less indraft. At a considerable distance from the center, and before the barometer shall have fallen much below its normal value, the center may bear 10 or 12 points from the direction of the wind (reckoned to the right or left according to the hemisphere); but after *the barometer has fallen five or six-tenths of an inch* it is probable that the

wind then blowing forms part of the central storm circle, and the bearing of the center may be taken as eight points from the direction of the wind.

It was said that the master's first care will be to know how the center bears. His next care will be to know on which side of the storm's path his vessel is situated, and the direction in which the storm is moving. In the northern hemisphere if she be situated on the right-hand side or semicircle of a storm traveling to the westward—looking in the direction to which the storm is traveling—the wind will veer N.E., E., S.E., S., &c., or with the hands of a watch; on the left-hand side the wind will back N., N.W., W., &c., or against the hands of a watch.

Similarly, in the southern hemisphere, if the vessel be in the right-hand semicircle of a storm traveling to the westward—looking in the direction to which the storm is moving—the wind will veer S., S.W., W., &c., or with the hands of a watch; in the left-hand semicircle it will back S.E., E., N.E., N., &c., or against the hands of a watch.

In speaking of the shift of wind such a shift is meant as would be observed on a vessel hove-to; for if the vessel be moving faster than the storm, and in the same direction, the shift may be in the opposite direction to what has been stated.

If while the vessel is hove-to the wind be found to remain in the same direction, increase in violence, and be accompanied by a falling barometer, it is probable she lies in the path of the advancing storm—the most critical of all positions.

The wind in front of the storm-field is, from the nature of the case, directed across the path of the center; blowing towards the path on one side, and away from it on the other. Consequently, if we suppose the cyclone to be bisected by a line representing its path, a little consideration will show that in the semicircle on one side of the path, a ship running before the wind may probably be brought to cross the path of the storm in front of its center, and therefore under circumstances of the greatest danger; in the semicircle on the other side of the path a ship running before the wind will probably cross the path in rear of the center. The former of these semicircles has been called the "dangerous" semicircle.

When looking in the direction in which the storm is traveling the dangerous semicircle is always on the right hand in the northern hemisphere, on the left hand in the southern hemisphere; also in both hemispheres in the right-hand semicircle the wind, to a ship hove-to, always veers, in the left-hand semicircle it always backs. The semicircle with veering winds is the dangerous semicircle in the northern hemisphere; the semicircle with backing winds is the dangerous semicircle in the southern hemisphere.

The recurvature of the path always takes place towards the side on which the dangerous semicircle is situated, *i.e.*, to the right in the northern, to the left in the southern hemisphere. Hence in the northern hemisphere, so long as the vortex is traveling to the west, the winds in front of the advancing center are north-easterly; as the vortex turns to the north, the winds in front are easterly; and after it has turned to the eastward the winds in front are south-easterly. A similar sequence will arise in the southern hemisphere, but in the opposite order, the winds in front of the vortex beginning with south-east and ending with north-east when the vortex has turned to the eastward.

We derive, then, the following rules to find *the most dangerous wind*, supposing always that the track of the storm is such as is indicated above, recurving in about lat. 30° N. or lat. 26° S.—

NORTHERN HEMISPHERE.

Between the Equator and 30° N. lat......N.E.
About 30° N. lat..........................E.
Northward of 30° N. lat..................S.E.

SOUTHERN HEMISPHERE.

Between the Equator and 26° S. lat......S.E.
About 26° S. lat..........................E.
Southward of 26° S. lat..................N.E.

These winds are most dangerous, because in each case if the wind continues steady from that point and the barometer continues to fall rapidly the ship must be on the path of the storm and directly in front of it, so that she is in the position of greatest peril.

It is difficult to estimate the distance of the center of the vortex from a vessel.

This partly arises from the uncertainty as to the relation between the bearing of the center and the direction of the wind, and greatly from there being no means of knowing whether the storm be of large or small dimensions. If the barometer falls slowly, and the weather only gradually gets worse, it is reasonable to suppose that the center is distant: and conversely with a rapidly falling barometer and increasing bad weather the center may be supposed to be approaching dangerously near.

PRACTICAL RULES FOR SEAMEN IN TROPICAL CYCLONES.

When in the region, and in the season of revolving storms, be on the watch for the premonitory signs. *Constantly and carefully observe and record the barometer.*

When there are indications of a cyclone being near, heave-to and carefully observe and record the changes of the barometer and wind, so as to find the bearing of the center, and ascertain by the shifting of the wind in which semicircle the vessel is situated. Much will often depend upon heaving-to in time.

When, after careful observation, there is reason to believe that the center of a cyclone is approaching, the following rules should be followed in determining whether to remain hove-to or not, and the tack on which to remain hove-to:

Northern hemisphere.—If in the right-hand semicircle, heave-to on the starboard-tack. If in the left-hand semicircle, run, keeping the wind, if possible, on the starboard-quarter; and when the barometer rises, if necessary to keep the ship from going too far from the proper course, heave-to on the port-tack.

Southern hemisphere.—If in the right-hand semicircle, run, keeping the wind, if possible, on the port-quarter; and when the barometer rises, if necessary to keep the ship from going too far from the proper course, heave-to on the starboard-tack. If in the left-hand semicircle heave-to on the port-tack.

Both hemispheres.—When the ship lies in the direct line of advance of the storm—which position is, as previously observed, the most dangerous of all—run. And in all cases act so as to increase as soon as possible the distance from the center; bearing in mind that the whole storm field is advancing.

Heaving-to in both hemispheres.—If the ship be in the right-hand semicircle, heave-to on the starboard-tack. In the left-hand semicircle, heave-to on the port-tack; these being the tacks on which the ship will "come up" as the wind shifts.

In receding from the center of a cyclone, the barometer will rise, and the wind and sea subside.

It should be remarked that in some cases vessels may, if the storm be traveling slowly, sail from the dangerous semicircle across the front of the storm, and thus out of its influence. But as the rate at which the storm is traveling is quite uncertain, this is a hazardous proceeding, and the seaman should hesitate and consider all the circumstances of the case, particularly observing the rate at which the barometer is falling before he attempts to cross.

Cyclones of the South Indian Ocean.—The researches of Mr. Meldrum, Director of the Government Observatory at Mauritius, have shown that, in the South Indian Ocean, a vessel approaching a cyclone on its southern side almost always encounters a strong Trade wind, which freshens to a gale. It is difficult to tell when the Trade forms part of the storm *circle;* consequently the bearing of the center can seldom, in this position, be inferred from the direction of the wind.

It is therefore recommended under such circumstances to heave-to and watch the wind and barometer; when the wind has shifted decidedly to the east or south the passage of the center with respect to the vessel's position may be approximately inferred; and when the barometer *has fallen six-tenths of an inch* its height at the commencement of the storm, the bearing of the center may be taken as nearly at right angles to the direction of the wind.

If the wind shift from S.E. decidedly towards the south, run to the N.W. Or, if the wind remain steady at S.E., increase in force, the barometer still falling, it is probable the storm is advancing directly towards the vessel; in such case, the most dangerous of all, run to the N.W.

It is also stated that in the cyclones of the South Indian Ocean, north-easterly

and easterly winds often, if not always, blow towards the center. Such being the case, it is better to make as much easting as possible.

It might easily be shown, the same writer remarks, that all the homeward-bound vessels that put into Mauritius for repairs do so in consequence of damage sustained in a cyclone which they entered on its northern side. There is a strong temptation to such vessels to run on with a favorable breeze; but a freshening northerly or north-easterly wind, with a falling barometer, and threatening appearance of the weather, should warn them to heave-to in time.

PROGRESS IN MECHANICAL SCIENCE.

AN ABSTRACT OF SIR FREDERICK BRAMWELL'S ADDRESS TO THE MECHANICAL SCIENCE SECTION OF THE BRITISH ASSOCIATION.

From the "Journal of the Society of Arts."

After alluding to the formation of Section H, Sir Frederick Bramwell said: At our jubilee meeting at York, I called the attention of the section to the fact that in 1831, when the Association first met in that city, they arrived there laboriously by the stage-coach, and that practically the Manchester and Liverpool, the Stockton and Darlington, and some few others, were the only railways then in existence. I also called their attention to the fact that in 1831 there were but very few steamers. I find the total registered in the United Kingdom in that year was only 447. If under this condition of things, the proposition had been made in 1832 at Oxford, as it was made in 1882 at Southampton, that the next meeting but one of the Association should take place in Montreal, the extreme probability is that the proposer would have been safely lodged in a lunatic asylum, for suggesting that that which might have involved a six-weeks' voyage out, and a four-weeks' voyage back, could ever be seriously entertained.

* * * * * *

There are those I know who object that Section G deals too little with pure science, too much with its applications. It may be, as the members of Section G might retort, that it is possible to attend so much to pure science as to get into the unchecked region of scientific speculation. . . . I think all men, even although they be followers of science in its purest and most abstract form, will concur in the propriety of Section G dealing with engineering subjects generally as well as with abstract mechanical science. Once admitting this, I may ask—certain what the answer must be—whether there is any body of men who more appreciate and make greater use of the applications of pure science than do the members of this Section. Surely every one must agree that we engineers are those who make the greatest practical use, not only of the science of mechanics, but of the researches and discoveries of the members of the other sections of this Association.

Section A (Mathematical and Physical Science).—The connection between this section and Section G is most intimate. With any ordinary man I should have referred, in proof of this intimate connection, to the fact that the President of A this year is a member of the Council of the Institution of Civil Engineers; but when I remind you that it is Sir William Thomson who fills this double office, you will see that no deduction such as I have hinted at can be drawn from his dual functions, because the remarkable extent and versatility of his attainments qualify him for so many offices, that the mere fact of his holding some one double position is no certain evidence of the intimate connection between the two. But setting aside this fact of the occupancy of the chair of A by a civil engineer, let us remember that the accomplished engineer of the present day must be one well grounded in thermal science, in electrical science, and, for some branches of his profession, in the sciences relating to the production of light, in optical science and in acoustics; while in other branches, meteorological science, photometrical sci-

ence, and tidal laws are all important. Without a knowledge of thermal laws, the engineer engaged in the construction of heat motors, whether they be the steam-engine, the gas-engine or the hot air-engine, or engines depending upon the expansion and contraction under changes of temperature of fluids or of solids, will find himself groping in the dark; he will not even understand the value of his own experiments, and, therefore, will be unable to deduce laws from them; and if he make any progress at all, it will not guide him with certainty to further development, and it may be that he will waste time and money in the endeavor to obtain results which a knowledge of thermal science would have shown him were impossible. Furnished, however, with this knowledge, the engineer starting with the mechanical equivalent of heat, knowing the utmost that is to be attained, and starting with the knowledge of the calorific effect of different fuels, is enabled to compare the results that he obtains with the maximum, and to ascertain how far the one falls short of the other; he sees, even at the present day, that the difference is deplorably large, but he further sees, in the case of the steam-engine, that which the pure scientist would not so readily appreciate, and that is, how a great part of this loss is due to the inability of materials to resist temperature and pressure beyond certain comparatively low limits; and he thus perceives that unless some hitherto wholly unsuspected, and apparently impossible, improvement in these respects should be made, practically speaking, the maximum of useful effect must be far below that which pure science would say was possible. Nevertheless, he knows that within the practical limits great improvements can be made; he can draw up a debtor and creditor account, as Dr. Russell and myself have done, and as has been done by Mr. William Anderson, the engineer, in the admirable lecture he gave at the Institution of Civil Engineers in December last on the "Generation of Steam and the Thermodynamic Principles Involved." Furnished with such an account, the engineer is able to say, in the language of commerce, I am debtor to the fuel for so many heat units, how, on the credit side of my account, do I discharge that debt? Usefully I have done so much work, converted that much heat into energy. Uselessly I have raised the air needed for combustion from the temperature of the atmosphere to that of the gases escaping by the chimney; and he sets himself to consider whether some portion of the heat cannot be abstracted from these gases and be transmitted to the incoming air. As was first pointed out by Mr. Anderson, he will have to say a portion of the heat has been converted into energy in displacing the atmosphere, and that, so far as the gaseous products of the coal are concerned, must, I fear, be put up with. He will say, I have allowed more air than was needed for combustion to pass through the fuel, and I did it to prevent another source of loss—the waste which occurs when the combustion is imperfect; and he will begin to direct his attention to the use of gaseous or of liquid fuel, or of solid fuel reduced to fine dust, as by Crampton's process, as in these conditions the supply may be made continuous and uniform, and the introduction of air may be easily regulated with the greatest nicety. He will say, I am obliged to put among my credits—loss of heat by convection and radiation, loss by carrying particles of water over with the steam, loss by condensation with the cylinder, loss by strangulation in valves and passages, loss by excessive friction or by leakage; and he will as steadily apply himself to the extinction or the diminution of all such causes of loss, as a prudent Chancellor of the Exchequer would watch and cut down every unproductive and unnecessary expenditure. It is due to the guidance of such considerations as these that the scientific engineer has been enabled to bring down the consumption of fuel in the steam-engine, even in marine engines such as those which propelled the ship that brought us here, to less than one-half of that which it was but a few years back. It is true that the daily consumption may not have been reduced, that it may have been even greater; but if so, it arises from this, that the traveling public will have high speed, and at present the engineer, in his capacity of naval architect, has not seen how—notwithstanding the great improvements that have been made in the forms of vessels—to obtain high speed without a

large expenditure of power. I anticipate, from the application of thermal science to practical engineering, that great results are before us in those heat motors, such as the gas-engine, where the heat is developed in the engine itself. Passing away from heat motors, and considering heat as applied to metallurgy, from the time of the hot blast to the regenerative furnace, it is due to the application of science by the engineer that the economy of the hot blast was originated, and that it has been developed by the labors of Lowthian Bell, Cowper and Cochrane. Equally due to this application are the results obtained in the regenerative furnace, in the dust furnace of Crampton, and in the employment of liquid fuel, and also in operations connected with the rarer metals, the oxygen furnace and the atmospheric gas furnace, and, in its incipient stage, the electrical furnace. To a right knowledge of the laws of heat, and to their application by the engineer, must be attributed the success that has attended the air-refrigerating machines, by the aid of which fresh meat is at the end of a long voyage delivered in a perfect condition; and to this application we owe the economic distillation of sea water by repeated ebullitions and condensations at successively decreasing temperatures, thus converting the brine that caused the Ancient Mariner to exclaim, "Water, water everywhere, nor any drop to drink," into the purest of potable waters, and thereby rendering the sailor independent of fresh-water stowage.

Sir Frederick Bramwell then proceeded to refer to the application, by the engineer, of electrical science, and to several other of the subjects dealt with in Section A. He then treated of the relations of mechanical science to the other sections, and concluded with these words:

I trust I have now established the proposition with which I set out, viz., that not only in Section G, the section of mechanical science, but it is emphatically the section of all others that applies in engineering to the uses of man the several sciences appertaining to the other sections; an application most important in the progress of the world, and an application not to be lightly regarded, even by the strictest votaries of pure science, for it would be vain to hope that pure science would continue to be pursued if from time to time its discoveries were not brought into practical use.

Under ordinary circumstances I should have closed my address at this point, but there is a subject which at this, the first meeting of Section G after the meeting at Southport, must be touched upon. It is one of so sad a character that I have avoided all allusion to it until the very last moment, but now I am compelled to grapple with it.

In the course of this address I have had occasion to mention several names of eminent men, many of them happily still with us, some of them passed away; but I doubt not you have been struck by the absence of one name, which of all others demands mention when considering physical science, and still more does it come vividly before us when considering the application of science to industrial purposes. I am sure I need not tell you this name, which I can hardly trust myself to speak, is that of our dear friend William Siemens, whose contributions to science, and whose ability in the application of science, have for years enriched the transactions of this section, and of Sections A and B, for in him were combined the mechanic, the physicist, and the chemist.

But a brief year has elapsed since he quitted the presidential chair of the Association, and, with us at Southport, was taking his accustomed part in the work of this and of other sections, apparently in good health, and with a reasonable prospect of being further useful to science for many valuable years to come. But it was not to be; he is lost to us, and in losing him we are deprived of a man whose electrical work has been second to none, whose thermic work has been second to none, and whose enlarged views justified him in embarking in scientific speculations of the grandest and most profound character. Whether or not his theory of the conservation of the energy of the sun shall prove to be correct, it cannot be denied that it was a bold and original conception, and one thoroughly well reasoned out from first to last.

I feel that were I to attempt anything like the barest summary of his discoveries and inventions, I should set myself a

task which could not have been fulfilled had I devoted the whole of the time I had at my command to the purpose. I had, indeed, thought of making his work the subject of my address, but I felt that his loss was so recent that I could not trust myself to attempt it. There is no need for me to dwell further upon this most painful topic. He was known to you all, he was honored and loved by you all, and by every member of this Association he had so faithfully served, and over which he had so ably presided; and he enjoyed the respect and esteem of the best intelligence of England, the land of his adoption; of the Continent, his birthplace; and of Canada, and of the United States, whose populations are always ready to appreciate scientific talent and resulting industrial progress. It is not too much to say that few more gifted men have ever lived, and that with all his ability and talent he combined a simplicity, a modesty, and an affectionate disposition that endeared him to all.

I am sorry to conclude my address to you in this mournful strain. I have endeavored to confine my allusions to our dear friend within the narrowest limits, but if I have overstepped these I trust you will forgive me, remembering that "out of the fullness of the heart the mouth speaketh."

LAKE MŒRIS AND THE PYRAMIDS.*

By COPE WHITEHOUSE.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

IN 1881, during the York meeting of the British Association, a paper was read under the title of The Topography of the Pyramids and their connection with Lake Mœris, the Bahr Jousuf, Labyrinth and Sphinx. It was shown that if the accounts of the ancient historians were treated as the honest efforts of intelligent men to describe what they had seen and heard there was no difficulty in blending their facts into a harmonious whole. The result, however, was so stupendous in its area of operations, the amount of human labor, the boldness and originality of the engineer, the wisdom of the government and the patience of the nation, that it could not be readily grasped, even by minds accustomed to the greatest works of centralized power. It was far easier to deny than to comprehend it. There are apparent contradictions in every great advance in knowledge. Light without smoke or heat has recently been obtained by electricity. The corridor of an Egyptian sepulcher, lined with colored *bas reliefs* carved on fine-grained limestone after these blocks had been placed in position, had, for thousands of years, proved to the world by an ocular evidence which none could deny, that light could be separated from all that tended to impair health or injure works of art by imperfect combustion.

Ancient authors had agreed in describing a reservoir of Nile water, formed artificially, fifty miles to the south of Memphis (Cairo), and twenty to the west of the Nile Valley, with 450 miles of indented sea-coast, containing islands, teeming with 22 sorts of fish, fed by a canal with double mouth, filled each year from high Nile. The water, stored by dams or levees, which it cost $70,000 annually to open and replace, was allowed to flow over the fields at low Nile for irrigation, or carried by tortuous, secret, subterranean channels into the local reservoirs of distant towns. "Mœris," they said, whether *meri* the beloved, or *Mer-uer* the great sea (cf. *mare* Lat. *mer* Fr.) was the grandest triumph of man over nature accomplished in all the long period of Egyptian history marked by rock-hewn temple, obelisk, or colossus, and throughout the length of the river from the Soudan to the Medi-

* This paper was withdrawn from the regular programme of Section E. of the American Association for the Advancement of Science, because it required lantern slides, and was read in the Academy of Music, Philadelphia, September 10th, and repeated (by request) in the Theatre of the Union League Club, September 12, 1884. The subject was presented to the New York Academy of Sciences, and discussed March 24, (see *Critic*, April 5th), and to the American Society of Civil Engineers, Buffalo, July 12. (See Reports in *Engineering* and other Journals).

terranean. "But," said the modern Egyptologists with absolute accord, "no such Mœris ever existed." There are, it was explained, the remains of dykes on the upper plateau of the Fayoum, which show that a pond or pool covering about 65 square miles was at one time formed and used to irrigate that province, and M. Linant de Bellefonds had, it was said, rendered the world a service in exposing the errors and absurd exaggerations of Herodotus, Strabo, Diodorus and Pliny, allowed to pass uncorrected, or repeated, by Ptolemy, Stephen and the geographers of Alexandria and Constantinople. The Bahr Jousuf was shorn of its antiquity and reduced to a work of Saladin (*Encyc. Brit.*). The Labyrinth became, under the exploration of Dr. Lepsius, a pile of mud bricks of no importance, with the scant remains of a small temple. The Sphinx nevertheless continued to smile impassively and offered itself as an impenetrable riddle to philologist and historian, astronomer and engineer.

Three years ago, therefore, if each of the factors of this whole was closely examined, its importance and character defined by the latest researches, and the accepted conclusions of recognized experts substituted for the terms used by a Strabo or a Pliny, the splendid fabric, reared high above modern thought and modern attainment, seemed to have been a distorted reflection in the mirror of tradition, seen by men who lent a credulous eye and eagerly transmitted fables founded upon truth, but on so scant a measure of it, that a tenth or a hundredth became a standard division by which to reduce their dimensions to actual fact.

As the objections, however, to the ancient authors were successively examined it became evident that no serious impression had been made upon their credibility. The acuteness of Voltaire and the geology of Linant Pacha were equally at fault. Bunsen, bewildered by the personal assurances of Dr. Lepsius, lost himself in a Labyrinth which was pure fiction. Centuries before the Crusades, the Canal of Joseph was a familiar word in Arab legend, and a measure of human enterprise in irrigation works in the Valley of the Euphrates. The map of Egypt in 1881 was a blank, where a deep dry southern basin has since been found. In 1882 and 1883, accordingly, researches had been made which gave to Lake Mœris all the attributes ascribed to it, in papyrus and on parchment, in picture, legend, and sober history.

It followed as a direct consequence from the rehabilitation of Lake Mœris that other assertions were restored to importance. If there was a lake 300 feet deep, there was also an island "as near as may be in the middle, with two pyramidal summits, 600 feet in height from the bottom of the lake, and 300 feet from the surface of the water" (Herodotus). The king who made the lake had "left a place" and constructed a tomb together with two pyramids. The piles of stone by which the upper half of this mass of rock was *revetted*, or into which it had been quarried and shaped, served by their height to show to those who sounded the shallow eastern plateau that it sank into a deep erosion (*fossa grandis*, Pliny) under the steep shores of horizontal limestone which bounded it on the west. On the first publication of these discoveries in Paris, in the *Revue Archéologique* (*Juin*, 1882) and in London, in the *Proceedings of the Society for Biblical Archæology* (June 1882) sections across the Nile Valley were given. One of these has been reproduced in the *Century* (October 1884). These show that the popular conception of Egypt above the Delta as a plain is entirely erroneous. The ancients invariably spoke of the two sides of the Valley as the Arabian (eastern) and Libyan (western) mountains. These steep cliffs of 400 to 800 feet are not the result of any upheaval. The dead level of the Libyan Desert is the last stratum of a cretaceous deposit, through which the waters of the Abyssinian highlands and Equatorial Africa have cut their way. The Nile now flows along the eastern shore of the cañon, and fills the lower level of it when high. To the west there are old channels, deeply scored by waterfalls in beds now dry, which are as much as 300 feet below the river and 200 feet below the sea. Everywhere scattered throughout this Libyan Desert are hills, pyramidal in form, with the axis in the line of erosion, with their bases sometimes 200 feet below the Mediterranean, but often rising as much as 800 feet above the valley of the Nile.

In the Wadi Reian the southwestern

basin of Lake Mœris, there is a hill, never before visited, known as the Haram. This word is applied exclusively to Pyramids by the Arabs. This hill is not a pyramid, but, like the island in the present lake, it justifies the ancient authors by affording a proof that "a place might be left" (by erosion) where a structure 600 feet high could be formed with a small amount of labor to serve as a monument of the immense natural wealth added to Egypt by the construction of its vast storage reservoir. If the Pyramids are to be treated as a class it is evident that a common factor must be found for them. It is difficult to assign them definite attributes. Prof. Perrot has, with great clearness shown that neither shape, dimensions, material nor purpose seem to have been their *raison d'être.* It has been insisted that the *first* of Gizeh, commonly called Cheops is an ideal pyramid and that the others are imitations. This opinion is only entertained by those who find mysterious significance in its corridor and coffer or sarcophagus. There is one factor which had necessarily been overlooked, all the pyramids are now seen to be (or to have been) either in, at, or near Lake Mœris and on the terrace above the high-level canals and aqueducts which were the conduits of its precious water. The Pyramids in the Nile Valley (like those in the lake) are lower than the level of the desert and are parts of islands or isolated hills formed by erosion before the Nile had cut its way at its present level between the commanding heights of Abu-Roash, crowned with a low pyramidal structure containing chambers in the live rock similar to Cheops, and the Mokattam with the citadel of Cairo, its extraordinary well and legends. The pyramids in Mœris were 600 feet high and yet natural hills. Medoum, the most southerly of the Pyramids is, like Abu-Roash the most northerly, only a hill, squared into shape and protected by walls of hewn stone. Its chambers are far above the valley and within the stone casing. They are, nevertheless, like every other chamber found in or under every other pyramid except Cheops, wholly in the natural rock. The two pyramids of Gizeh cannot be dissociated. They are termed *the twins,* and they have borne a fraternal relation from their first appearance in history. "They are," said Pliny, "on the African side on a barren stony mountain," but Strabo, with an accuracy in which he had been preceded by Herodotus, described them as *in* the brow of a hill, and not on its summit. This hill is over 150 feet above the plain. It rises within Cheops a certain height, not less than 40 feet above the socket stones which have been regarded as the base of the structure. It also rises to a much greater height at its western summit and sinks again abruptly to nearly the level of the Nile. North and south it is bounded by ravines, so that if the Nile rose but a few feet higher, the hill of the Gizeh plateau with its pyramids would become an island. If a horizontal plane be passed through the summit or even through the apex, supposing that the sides were coated and carried to a point, it would not be as high as Abu-Roash, 5 miles to the north, the Mokattam, 8 miles to the east, or the Kom el-Kashab, 9 miles to the west. Opposite to Gizeh, on the east bank of the Nile are immense subterranean quarries, about 100 feet above the plain. It was a natural inference that the stone of the Pyramids had been taken from these quarries. But it is evident that this cannot have been the case. Apart entirely from the obvious absurdity of sending to the opposite side of a swollen stream, 8 miles wide, for material which lay at hand and which was good enough for every purpose, and deemed quite good enough to use in every other pyramid on the west bank, the stones now visible on the exterior of Cheops could not have been quarried in the interior of a hill. Many of these blocks are deeply pitted or worn by water. They show marks of exposure to a disintegrating agent infinitely more powerful than the feeble action of sun or wind with an occasional shower. They are parts of the crust of a limestone hill, roughly broken perpendicularly, retaining their natural horizontal surfaces as each layer could be pried off any of the exposed edges of the strata of rock, laid bare and worn by the waters at their old level. It is therefore not a question of probability merely but approximates to an absolute demonstration that these twin masses of coarse and worthless limestone, broken into convenient blocks and piled without regard to any consideration except stability and the angular form which would protect the adjacent terrace

from hot winds, laden with sand, could, with due regard to the ordinary operations of the human mind, the geological conditions of the rock, the engineering methods of the ancient world and similar structures still standing, have been formed out of natural hills, each block moved but a short distance, usually downwards, into chambers quarried in the hill itself, until a solid mass was made as the quarrymen "backstoped" upwards through the hill. They could then return over the outside, using the crust as a revetment and making a Pyramid which only differed from Medoum by the increased labor due to the frail character of the original hill, honeycombed with sepulchral chambers, temples or quarries. All tradition confirms this. "I have built the Pyramids," said Surid, "to provide against the dreadful consequences of the Deluge which is to overwhelm the earth." But it was *Mœris*—the great sea—of which, the two Pyramids in the lake, 600 feet high, were also monuments, which saved the Delta from the dread scourge of the annual flood. Hermes "brought the people from the mountains where they had retired for fear of the waters, and taught them to cultivate the plains." In these traditions as well as in the statement of Herodotus that these pyramids were built "from above," were completed "outwards," by a king who shut *down* the (rock-hewn) temples," at an uncertain date, for "all the authors do not make it clear who built them" (Pliny), and the silence of the Egyptian records, geographical, historical and poetical, led the author of this paper to affirm as a probable conclusion from well-established facts, in accordance with the principles of sound reasoning, that the huge piles at Gizeh are the results of a creditable effort to convert an unsightly and dangerous hill into a solid mass with some further purpose which modern science has not fully grasped.

The various steps in this argument were illustrated and proved by photographs of papyri, ancient and modern maps, sections of the Nile Valley from personal and original surveys, sketches and photographs of natural hills of pyramidal form in Egypt and Nubia, with examples of denudation of horizontal beds elsewhere, the quarries of Turra, the natural strata in the head of the Sphinx and under the Pyramids of Gizeh, and the sides of the Kom el-Kashab, Abu-Roash and the Mokattam. The partially completed façades of Petra were begun at the top. The limestone quarries of the Nile were worked in "stopes" or ledges, in subterranean chambers and passages. Evidence was also furnished that these facts and suggestions had been put before the scientific world in definite form, and had elicited the approval of competent judges. The survey of the Desert to the west of the Pyramids was inserted by Prof. Perrot and M. Chipiez in their history of Egyptian Art (Eng. Ed., 1882). The London *Academy* described with approval how it had been "conceived that the Gizeh plateau was once a range of hills, weathered into fantastic shapes, to which horizontal strata gave an artificial appearance and pyramidal summits," and "the inferior material was cut into blocks, lowered from above and pushed into place to build the Pyramids." The Wadi Reian, eroded to a depth of two hundred feet below the Mediterranean, and the hills in the Wadi Fadhi have been placed upon the map of the British War Office. The Geographical Society of Cairo, 1883, indorsed the surveys of 1882 and 1883 as a new and important contribution to the cartography of the Libyan Desert. The Dutch Academy of Sciences (1884) republished the geographical Papyrus of Boulaq with a map to show that this document had been, hitherto, wrongly interpreted, but the Abbé Amelineau had already demonstrated this at length in the *Revue des Questions Historiques*, (Oct., 1883). The Report of the New York Academy of Sciences (*Critic*, April 5th, 1884), refers more particularly to the proof that "horizontal limestone once filled the Nile Valley to the height of nearly a thousand feet, and several hundred feet above the tops of the Pyramids," and that "the tombs under the Pyramids appear to be older than the structures above," while the granite blocks (from Assouan) and coffer, being too large to have been brought through the entrance and passage, may have been put into the hill before it was reconstructed into a pyramidal pile of rough-hewn stones.

The Society of Civil Engineers at its meeting June 12, 1884, (see the *American Engineer*) agreed that the stones

might have been actually quarried in a hill and lowered into their present position so that the amount of labor would have been exceedingly small in comparison with that required to construct the piles by concentric and successive layers. At the meeting of the British Association for the Adv. of Science in Montreal (Aug. 27, 1884) reported in the Oct. No. of the Proceedings of the Royal Geog. Soc., the accuracy of the ancient historians was shown and the use of technical words explained. The restoration of the South-Western basin (see *Saturday Review*, Jan. 25th; 1883; *The Century*, October, 1884) was advocated. The Ptolemaic maps were justified by the levels run by theodolite and spirit level as well as aneroid barometer, alone or with the aid of Messrs. Ellis, Gasperoni, Petrie and others. Wide fields of archæological research were indicated and a hieroglyphic inscription from Edfou cited as conclusive of the former extent of Lake Mœris, while the complete absence of early reference to the Pyramids confirms the conjecture that they are comparatively modern, and did not exist in the time of Rameses-Sesostris. The reopening of Lake Mœris would greatly facilitate an Alexandria-Cairo-Suez Canal.

It is obvious that unless these facts are contradicted, it is legitimate to infer that the situation of the Pyramids is an important factor in the question of their purpose. The problem of their construction is to find the easiest and most natural method. Why hills at, in or near Lake Mœris should have been revetted, or reconstructed, into square or rectangular masses with sloping sides may never be explained, but, even in that event, a stigma is removed from the history of the human race, and especially from its engineers, by showing that these are not piles of stone, quarried on the right bank of the Nile and transported to the left bank, only to serve as a tumulus above or around the nameless sarcophagus of an unknown personage.

THE MANCHESTER SHIP CANAL SCHEME.

By H. S. S. SMITH, C. E., Princeton College.

Written for Van Nostrand's Magazine.

The proposition to make Manchester a sea-port is not a new one. Like every great undertaking, it has been preceded by various plans to accomplish the same purpose. Forty years ago Mr. Palmer agitated the question, and since then Mr. Bateman and Mr. Fulton have been earnest in their endeavors to have the idea reach actual achievement. It is, in a certain sense, unfortunate that the present discussion of the subject has thus far been barren of material results, for no one denies that the proposal, if practicable, would be of great benefit to a large and active manufacturing center. But the grounds on which permission has been denied by Parliament are evident and reasonable, and it remains to be seen whether or not the same object can be reached in a way that will not be detrimental to existing interests.

The present agitation of the question took a definite form in June, 1882, when a provisional committee was formed in Manchester and began active operations by appointing Mr. Hamilton Fulton and Mr. E. Leader Williams engineers to prepare reports and estimates of the proposed undertaking. Each of these engineers made a report to Mr. Abernethy, the consulting engineer, the two plans being so radically different that it was impossible to combine them into one. Mr. Fulton's proposal was "to straighten, deepen and widen the Irwell and Mersey between Trafford Bridge, Salford and Liverpool so as to afford a depth of 22 feet at low water of spring tides." As this plan would require a rock-cutting 40 feet deep and 10 miles long, and would place the docks at Manchester 92 feet below the present surface of the ground, the report was not adopted by Mr. Abernethy. The report made by Mr. Williams was essentially different, and was the basis of the proposal that was laid before Parliament. He proposed to excavate a ship canal in the

valleys of the Irwell and Mersey from Manchester to Runcorn, a distance of 21.25 miles. This canal was to have locks, worked by hydraulic power, with steam reserve in case of drought. From Runcorn the channel in the estuary was to be straightened and deepened by dredging and by the erection of training walls. There would thus be two distinct parts to the work, the canal portion from Manchester to Runcorn, and the estuary portion from Runcorn to the deep water just above Liverpool. Mr. Williams made detailed plans and estimates for the former, but it would appear that no estimates were made for the portion of the work below Runcorn.

A bill was drawn and brought before Parliament, but, as the standing orders had not been fully complied with, it was admitted only by special permission, and after considerable debate. The supporters of the bill were the merchants and local boards of Manchester, the chambers of commerce of many places that would be benefited by the works, and the manufacturing interests generally. The opponents were the railway companies having lines between Liverpool and Manchester, the various local boards of Liverpool, and the harbor boards and navigation companies having interests in the river Mersey. That the canal was needed, and would be beneficial to a large volume of trade, was proved beyond doubt. But the lack of definite plans and estimates for the estuary part of the work told heavily against the promoters of the enterprise. The committee of the House of Commons, after a patient and thorough investigation, lasting thirty-seven days, passed all of the bill excepting that portion referring to the work in the estuary, reserving decision on it until full plans and estimates should be laid before them. The Committee of Lords, after a brief and superficial inquiry, decided that it was not expedient to proceed with the subject during that session.

The time intervening between this and the next session of Parliament was spent by the promoters in altering the location and plans, and perfecting the estimates of the canal part, and in designing the plans for the channel in the estuary. When the bill came again before Parliament there were no formal technicalities to contend with, but the opposition produced strong engineering arguments against the scheme. Committees investigated the matter as before, and the result was that the Lords passed the bill, while the Commons Committee refused to do so. It is said that $1,500,000 have already been spent in promoting and opposing the bill. As there is reason to believe that the real cause of the defeat of the bill was the engineering evidence produced by the opposition, it will be interesting to study the circumstances of the case, and see what the conditions really were.

To understand the plans it will first be necessary to give a brief description of the existing waterway from Manchester to the open sea. The city is situated on the Irwell, a small stream having a depth of only four feet under favorable circumstances. Flowing westward from Manchester, it joins the Mersey after a winding course of about 6 miles. The direction and character of the stream remain practically unchanged to Warrington, 15 miles below Manchester. From this place to Runcorn, 6 miles below, the limit of draught is 9 feet. At Runcorn the river meets the estuary, a basin whose shape is that of an irregular crescent, the direction of the general axis changing from nearly westerly at Runcorn to nearly northerly at Dingle Point.

The length of the basin is about 12 miles, and the area is 27.2 square miles. At low water about 20 square miles of sand banks are uncovered, and the channels between have an effective depth of but 12 feet. The banks and channels are subject to continual and rapid change under the action of the tide. The outlet is a channel extending from Dingle Point to Rock Lighthouse, about 5.5 miles in length, and from 0.6 to 1.0 mile in width. This channel is lined with docks on both sides, Liverpool being on the east and Birkenhead on the West: and, although the mid-channel at low water has a depth of 70 feet, the deposition of silt in the dock slips is so steady that constant dredging is necessary to preserve their usefulness. Rock Lighthouse is at the head of Liverpool Bay. The two parts of the shore of the bay are nearly at right angles to one another, the eastern shore inclining slightly west of the direction of the channel from

Dingle Point to Rock Lighthouse, and reaches to Formby Point, while the southern shore extends in a direction a little south of west to Hoylake Lights, near the mouth of the river Dee. From Rock Lighthouse to the open sea the distance is about 11 miles. The whole of the bay is occupied by banks and shoals, about 34 square miles being entirely uncovered at low water. There are two main channels across the bay. The principal one, Crosby Channel, is a continuation of the Mersey from Rock Lighthouse to Crosby Light, and then turns to the north-west and crosses the bar at the Bar Lightship. A less important one is the Rock Channel running westward from Rock Lighthouse along the Southern shore of the bay nearly to Hoylake Lights, and then turning north to the bar. Across the entire seaward face of the bay there is a bar that gives, when in its best condition, a depth of only 12 feet at low water. The banks, channels and bar are constantly changing under the wear of the tides, and, although the changes are not particularly rapid, they are sufficient to demand constant watching on the part of the harbor authorities.

While the character of the bottom and the configuration of the shores render the channels and harbor far from convenient and safe for shipping, the height and violence of the tide add much to the complexity of the situation. The total rise of an ordinary tide is 30 feet. The water, coming from the west, and confined between limits that are continually narrowing, develops a high silt-carrying capacity. In the channel between Rock Lighthouse and Dingle Point the velocity of the tidal current is as high as 5.5 miles an hour. Reaching the broad basin between Dingle Point and Runcorn the velocity and, consequently, the silt-carrying power are much diminished, and a rapid deposition of silt takes place. This action is rendered more complete by the fact that for more than half the length of the estuary high water occurs at the same time, and the surface is consequently level. The surface remains level for 2 hours and 40 minutes, and although it falls 13.5 feet in that time the current is scarcely perceptible. From this condition of things there results a rapid and almost complete deposition of the silt brought in by the flood tide on the higher banks in the basin. As these banks are, in many places, only five feet lower than high-water level, by the time the ebb currents begin to run with any decided velocity they have become completely uncovered, and the silt deposited on them by the flood is above the reach of any erosive action. But the velocity of the water in the low water channel is sufficient to enable it to carry a large amount of silt, and the banks of these channels are being continually undermined and broken down by the wearing action of the water in a way quite similar to that shown in the caving banks of the Mississippi. This action produces constant change in the position of the channels, a change so prominent that monthly surveys of the estuary are necessary in the interests of navigation, and the buoying of the channels is a matter of constant care. Although the changes are constant the results are remarkably uniform, the amount deposited by high water and the amount excavated by the low-water currents being just about equal day after day and year after year. The action of the tide in Liverpool Bay is to change the banks and channels to some extent, but not rapidly, while its principal effect is in keeping the bar scoured down to a depth that permits navigation. The bar is the most troublesome part of the entrance to the Mersey, and while the depth at low water is seldom more than 12 feet, and thus prevents continuous passages by ocean steamers, it is considered by the harbor authorities at Liverpool as better than none, and must not be meddled with.

The plans for the canal from Runcorn to Manchester showed an engineering project of large dimensions, but free from any special difficulty. In section, the canal would have a breadth of 120 feet at the bottom, side slopes of 1.5 to 1 in earth, but varied in rock, and a depth of 26 feet. The locks would all be similar in plan, but with different lifts. The plan shows three separate basins side by side, 550 by 60 feet, 300 by 40 feet, and 100 by 20 feet, respectively. Sluices were to be built in connection with each set of locks to pass the overflow and storm waters into the lower levels.

Starting from the Mersey at Astmoor

Marsh, about a mile above Runcorn, the canal would keep a straight westerly course for 9.75 miles. At 0.75 miles from Astmoor Marsh is placed the first set of locks, providing a lift of 17 feet at low tide, while high water would flow 5 feet above the intended water level. It was intended that this five feet of water should be used to scour the canal and the channel in the estuary at low water. At 4.5 miles, near Warrington, the London and Northwestern, and the Birkenhead, Lancashire and Cheshire Railways are met. In order that these might pass at a sufficient height it would be necessary to raise the grades at crossing some 43 feet, and the approaches would be about a mile long on each side and have gradients of 1 in 132. To accommodate the trade at Warrington, it was determined to build there a dock 20 acres in extent, with lines of track running from it to the railways. The dock would be connected with the Mersey by a small lock suitable for river craft. At 7 miles the Warrington and Stockport branch of the London and Northwestern Railway would be passed, the plan of passing being the same as for all the other railways. At 7.25 miles there would be the Latchford locks, with a lift of 15.5 feet. The canal would then follow the valley, but would be independent of the river, crossing the bed of the river several times. Below the limit of tidal flow at Woolton Weir the river would be diverted, but above that point the proposition was to turn all the water of the Irwell and Mersey into the canal, and to fill the bed of the stream thus abandoned with earth from the canal cuttings. At 13.25 miles the canal would pass under the Liverpool and Stockport Railway, and at 14.5 miles, under the Liverpool and Manchester Railway. In each of these cases it would be necessary to raise the grades 40 feet, and to make the approaches in the same manner as for the other lines. At 14.75 miles there would be the third set of locks, the Irlam locks, having the same plan and sluices as the others, but with a lift of 13.5 feet. The work just below these locks would be heavy, but it would seem better to have the railways cross the lower level. Continuing to follow the valley with gentle curves the canal, at 17.25 miles, would reach the last set of locks at Barton. These would be the same as those at Irlam. At 18.1 miles the canal would pass under the Barton aqueduct of the Bridgewater Canal, built by Brindley in 1760. It would be necessary to make some arrangements to get the ships past this, as the headway would be insufficient. It was proposed to build a new aqueduct, of which a part should be an iron trough balanced on a central pier and fitted with watertight gates, so that it could be swung around in the manner of a drawbridge. From this place to Manchester the canal would follow the valley of the Irwell, and finally reach the proposed site of the docks, 21.25 miles from the beginning of this portion of the work. It was proposed to take the Manchester Racecourse grounds for the docks of the ship canal. The surface would be 6 to 8 feet above the water surface, and by excavating a water space of 70 acres to the depth of 26 feet, it was expected to give accommodation to 1,260,000 tons of shipping per year. By widening and deepening the Irwell above the docks this could be increased to a capacity of 1,800,000 tons with the additional advantage of improving the connection between the ship canal and the smaller canals centering at Manchester. It was estimated by the engineers that this portion of the work would cost $25,800,000, and could be completed in four years.

The construction of the works in the estuary presented a problem containing many uncertainties. The general plan was to construct training walls from the end of the canal to Garston Docks, a point about 4 miles above Dingle Point, and thus cause the low water channel to keep a definite position. This channel would gradually increase from 300 feet to 1,000 feet in breadth, and would be dredged to a depth of 26 feet at low water. It was found that there was good foundation, either of rock or gravel, at a reasonable depth on which these walls could be built. Materials for the walls would be easily obtained from the rock cuttings on the canal. The difficulty lay, not in the construction, but in the probable effect of the proposed training walls on the tidal flow in the estuary, on the deposition of silt, and on the tidal capacity of the basin. It was proposed by the promoters of the scheme, and the proposition was sanctioned by the surveyor

of the port, to make the walls of such a height that they would "never remain wholly uncovered during the whole of any neap tide." It was argued that by so doing the tidal capacity of the basin would not be decreased, but, on the contrary, would be increased, by the deepening of the channel that would result from the constant scouring. It was argued that the increased velocity that would result would increase the silt-carrying power, and that the proposed improvements would not only serve the purpose for which they were made, but would result in a permanent improvement of the channel from Dingle Point to and across the bar. While this reasoning seemed very just on the face of it, it was proved to be false reasoning on insufficient grounds, and it was here that the opposition made a successful stand. The Mersey Dock and Harbor Board, opposed to the construction of the canal because the trade at the Liverpool docks would be much decreased thereby, engaged Mr. J. B. Eads to investigate the subject of the tides in the estuary and bay, and to report on the probable effect of the construction of the proposed training walls on the tidal capacity of the estuary and on the channels in the bay. The results of his investigations on the tides, and the manner in which they carry and deposit sediment and keep the capacity of the basin uniform have been already given. Bearing the facts in mind, it will be comparatively easy to trace out the sequence of results that would follow from the construction of such walls as were proposed. The deposition of silt on the shoals in the estuary would, at first, be as before; but the wearing action of the low-water currents on their banks would be stopped by the training walls, and there would result an inequality between the gain and loss of silt in the shoals with a balance in favor of the increase. This would soon raise the height of the shoals nearly to the level of high tide, and the capacity of the basin would be decreased by an amount nearly equal to this, for the increase of capacity coming from the increase of depth of the channel would be small in comparison with the volume occupied by flood tide. The tidal capacity of the basin being thus decreased by the gradual deposition of silt on the shoals, the volume of water transported as tidal flow would be correspondingly lessened, and the velocity of the tide would be reduced. This reduction in velocity means a still greater reduction in silt-carrying capacity, because this latter varies as the square of the velocity. The reduction of volume, velocity and silt-carrying capacity would be effective, not only in the estuary between Dingle Point and Runcorn, but also in the channel between Dingle Point and Rock Lighthouse, and over the whole extent of Liverpool Bay between the lighthouse and the bar. The result would evidently be that the depth of the channel opposite Liverpool would be lessened by silting, and that even the present shallow depth of water on the bar would be decreased. These facts and their logical results were placed before the Parliamentary committees in a clear and forcible manner, and it is not strange that they refused to pass the bill.

It has been admitted on all sides that the proposed undertaking was one that would be of very great benefit to a large and active manufacturing center, and because one plan has been proved to be not feasible is no reason for thinking that the object in view cannot be attained. There are still at least three ways of providing a deep water channel from Manchester to the sea. One of these would, at the same time, greatly benefit the communication between Liverpool and the sea, while the other two would have no influence at all on the existing waterways below Dingle Point.

The expedient suggested by Mr. Eads, in answer to questions put to him when before the committees, was to construct a ship canal similar to the one proposed, but extending all the way from Manchester to the sea. That is, instead of entering the estuary of the Mersey at Runcorn it would pass to the south, skirt the Cheshire shore of the estuary, and enter tidal waters somewhere between Rock Lighthouse and the mouth of the river Dee. Although no detailed estimate of this work has been made, it would appear that there would be no great difficulty in the way of such a plan.

While it must be acknowledged that a close acquaintance with the hydrography of the place is necessary to warrant the elaboration of a scheme for realizing the

desired end, a close scrutiny of the many facts that have been elicited by the agitation of the question fails to show why either of the following schemes would be impracticable when viewed from an engineering standpoint. Each of them would, however, seriously and completely interfere with the riparian rights along nearly the whole of the present shore of the estuary.

The first one to be mentioned, the less expensive one of the two, and the one that would have no prominent influence on the channels and bar of the bay, is this: Starting from the proposed terminus of the canal proper at Runcorn, construct two training walls whose tops should ultimately be above high water of spring tides, and place them at such a distance apart that at any place the area of the cross section between them occupied by the water that comes in at flood tide would be equal to the present area occupied by the flood on the same cross section; or, rather, so proportion them that the total volume between them occupied by the water of flood tide would be equal to the present tidal capacity of the estuary. Thus, opposite Ellesmere Docks the low-water channel has a breadth of 0.4 miles, while the remaining 3.1 miles are covered by shoals at low water. The breadth of an equivalent channel would be about 2.1 miles. Or, if these training walls were to be a uniform distance apart, this distance would be about 1.3 mile, in order to furnish the same tidal capacity as at present. At Dingle Point, or a little above, these walls should be made to join the shores on either side. Since the depth and uniformity of a channel have a great influence on the velocity and the consequent silt-carrying capacity of a tidal current, it would seem that the condition of the channels below Dingle Point would be improved by such a change in the estuary.

The second scheme is of much greater magnitude. It would make an unimpeded deep-water channel all the way from Runcorn to the open sea, by the erection of high-tide training walls from Runcorn to Dingle Point, and from Rock Lighthouse to deep water, leaving the channel between Liverpool and Birkenhead untouched. While this would diminish the tidal capacity of the bay and of the estuary, it would keep all of the tidal action within definite boundaries, so that there would be no opportunity for the formation of shoals. There would, however, be the probability of decided difficulty in the matter of the deposition of silt at and near the mouth of the channel. There is no large body of water flowing seaward to carry away the silt, as in the case of the Mississippi. It would be exceedingly difficult to predict what the depositing action would be, as it appears that some kind of a geological change is in progress in connection with the complicated tidal action.

With either of these schemes there would be the difficulty of leaving the present docks and water fronts along the shores of the estuary far removed from any navigable channel, and the formation between 10 and 20 square miles of new land between the proposed channel and the present shores. Whether these would be sufficient to prevent the carrying out of the plan is a question that must be decided on the spot. In any case, however, the formation of a deep-water channel from Manchester to the sea is not an impossibility, and will probably be an accomplished undertaking before the end of the century.

From a paper read before the Royal Institution by Professor J. W. Judd, it appears that the Krakatoa cataclysm destroyed over 35,000 people, but as a volcanic outburst it was comparatively small to that of Tomboro in 1815. The Krakatoa was, however, more violent for the few hours it lasted than the Tomboro during its thirty days. The size of Krakatoa was formerly 33½ square kilometers; of that 23 square kilometers have subsided, and 10½ square kilometers remain extant. But on the south and southwest side the island has been increased by a large ring of volcanic products, so that the size of New Krakatoa is now, according to the survey, 15¼ square kilometers. The size of Long Island was formerly 2.9 and is now 3.2 square kilometers. Verlaten Island has become much larger; it was formerly 3.7 and is now 11.8 square kilometers in size. Of the Poolsche Hoedje nothing remains. In the place where the fallen part of Krakatoa once stood there is now everywhere deep sea, generally 200, in some places even more than 300, meters deep. It is remarkable that in the midst of this deep sea a rock has remained, which rises about 5 meters above its surface. Close to this rock, which is certainly not larger than 10 meters square, the sea is more than 200 meters deep. It is like a gigantic club, which Krakatoa lifts defiantly out of the sea.

ON THE PRESERVATION OF IRON BRIDGES.

By E. PASCHEN.

From Abstracts of the Institution of Civil Engineers.

The author urges the growing necessity for the general adoption of some system, whereby the condition of existing iron bridges may be ascertained and recorded, and periodical inspections of all such structures be made in the future.

As regards the iron bridges erected in Germany, those upon the earliest constructed lines of railway, although not intended to carry the heavy class of locomotive now in use, were designed with such an ample margin of strength and constructed in so careful a manner as to be equal to the increased stress produced by the present type of engine; but with the progress of railway construction, investigation led to more familiarity with the direction and amount of strains upon bridge structure, and there ensued a desire, which seems to have become general, to economize the amount of metal to the utmost, basing the calculations upon the then existing conditions, and disregarding the possibility of the introduction of a heavier class of locomotive; so that, at the present time in many bridges, the metal, at the transit of every train, is subjected to strains in excess of that which is assumed to be permissible.

This applies more to small than large spans, as the amount of increased load, due to the use of heavier engines, is proportionally greater in the case of the former than of the latter. With the increase in the number and magnitude of bridges erected, a tendency to deterioration in the character of the work and material employed ensued.

The author mentions the failure in some instances of the hinge ("Pendel") bed-plate, and advocates the use of the usual expansion roller frame only, and, after enumerating the evils arising from various causes, such as the removal of the overhead transverse ties in the case of deep girders (causing lateral distortion), insufficient riveting at the intersection of lattice bars, inattention to condition of paint, and the non-provision of a sufficient thickness of timber between the rail and the ironwork of the structure, points out the necessity for the employment of competent inspectors during the progress of the work, both at the place of manufacture and erection.

Reference is made to the Society of Architects at Berlin, which has directed its attention to the question, and proposes that the railway companies generally should institute a system of periodical inspections and reports as to the condition of their various iron bridges, and recommend that the observations should be divided into two classes, the first (general) to be made in respect of every bridge, and the second in special instances only.

"The general observations (to be made every five years) to include—

"1. Measurement of permanent deflection.

"2. Measurement of deflection caused by loading (at rest).

"3. Enumeration of those portions of the structure and rivets which may have already been renewed.

"4. Careful examination of plates at junctions of bracing with booms, &c.

"5. Careful examination of paint and those places affected by rust.

"The special observations (to be made annually) to include—

"6. Deflection of the lower flange under a moving load.

"7. Distance apart of the top and bottom flanges.

"8. Length of the diagonals.

"9. Lateral distortion and vibration at the center of the girders.

"All observations upon the structure when repeated, to be, if possible, made by the same inspector."

In modification of the above the author suggests that the result of observations made by mere inspection should be kept separate from those obtained by loading, as the former could be made at any time at comparatively slight expense, and the most important of the defects discovered, whereas the latter would necessitate the presence of a sufficient number of en-

gines of the heaviest class, and for the time being, stop all traffic; he therefore proposes that subordinates should be first carefully instructed under the supervision of the chief inspector, and that afterwards it should be their duty frequently to examine the structures, a formal report from personal observation being made by him once in two years, and that the load-test should be employed only once in ten instead of five years.

The special observations, it is suggested, should include the effect of temperature upon the length of the girders, the amount of movement in the roller bedplate with trains moving in both directions, the comparative distances apart of the web-verticals, measured near the top and bottom flanges when the girder is loaded, and the lateral deflection caused by wind-pressure under the conditions of a loaded and unloaded girder.

The author recommends that a book should be kept for the entry of the inspectors' report, the information being under the following headings, viz., name, short description, and, where possible, the calculation of the strains, and a general sketch with details of the most important parts; weights of iron in the construction, total weight of superstructure; details as regards the history of the construction, name of maker, &c.; character of the materials, and results of experiments as to strength, amount of deflection under moving and fixed load, &c.

An example is given of an entry in the Bridge-Book, with a sketch referring to the Werda Bridge, a double-line structure of six 67-feet spans.

THE EFFICIENCY OF FLUID IN VAPOR ENGINES.

By H. L. GANTT, A. B., M. E., and D. H. MAURY, Jr., M. E.

Contributed to Van Nostrand's Engineering Magazine.

I. The determination of the efficiency of fluid of different vapors was suggested by Prof. R. H. Thurston to the writers as a subject demanding investigation.*

This suggestion was the more gladly accepted as the writers had desired to investigate, and if possible, to make a practical test of, a vapor engine, which was at that time awakening some interest in engineering circles in New York City and elsewhere. Failing to obtain permission to test the engine in question, the writers were compelled to confine themselves to a purely theoretical discussion of the subject.

2. Rankine, Clausius and others have proved that the amount of heat transformed into work does not depend upon the fluid which is the conveyor of that heat, but simply upon the limits of temperature between which the fluid is worked. It follows that, theoretically, all fluids are equally efficient in transforming heat into work; it does not follow, however, that all fluids are equally valuable as the working fluid of an engine, for there are other considerations beside efficiency to be taken into account in making choice of a working fluid. We have set ourselves the task of choosing the best working fluid from the following liquids: water, alcohol, ether, bisulphide of carbon and chloroform.

Case I.

3. This section is devoted to a discussion of Carnot's cycle, first in general, and then as applied to the vapors in question, with the object of showing that, while the efficiency of fluid is the same in each case, that of the engine may be different, and in general will be, since its efficiency will be less as the size of engine required to produce a given power is larger.

4. Carnot's cycle consists of an isothermal expansion, an adiabatic expansion, an isothermal compression, and an adiabatic compression up to the original temperature.

We shall suppose a certain amount of heat, L_1, to be worked in the cycle of Carnot, between the limits of temperature t_1 and t_2, by any fluid, and then by each of the fluids in question, and shall show that, while neither the work of expansion nor

* The writers take this occasion to express their gratitude to Professor Thurston for his great kindness in placing at their disposal his valuable library, and for the many other favors shown them during the progress of their work.

that of compression in any case is equal to the corresponding quantity in any other case, their difference, the effective work, is equal in all cases.

We suppose our fluid to be at the temperature t_1, and that we have just so much of it as will be evaporated by the heat L_1. The evaporation accompanies the isothermal expansion represented by AB, Plate I., Fig. 1. The adiabatic expansion BC, then takes place until the temperature falls to t_2; the isothermal compression is shown by CD and the adiabatic compression by DA.

5. Rankine gives as the formula for the rates of expansion necessary to reduce the temperature of steam from t_1 to t_2 *

$$r=\frac{\tau_2}{L_2}\left(JD_1 \log._e \frac{\tau_1}{\tau_2}+\frac{L_1}{\tau_1}\right).$$

τ_1=absolute initial temperature on the Fahrenheit scale.

τ_2=absolute final temperature on the Fahrenheit scale.

L_1=latent heat of evaporation of a cu. ft. of vapor at temperature t_1, in foot pounds.

L_2=latent heat of evaporation of a cu. ft. of vapor at temperature t_2.

D_1=weight in lbs. of cu. ft. of vapor at temperature t_1.

J=mechanical equivalent of heat in foot pounds.

This formula may be made applicable to all vapors by the introduction of K, the specific heat of the liquid, as follows.

$$r=\frac{\tau_2}{L_2}\left(JD_1 K \log._e \frac{\tau_1}{\tau_2}+\frac{L_1}{\tau_1}\right) \quad . \quad (1)$$

The formula for the work done per stroke, in a steam engine, by a unit volume of vapor at temperature τ_1 as given by Rankine † is

$$\text{Work}=JD_1\left\{\tau_1-\tau_2\left(1+\log_e \frac{\tau_1}{\tau_2}\right)\right\}+$$
$$+\frac{\tau_1-\tau_2}{\tau_1}L_1+r(p_2-p_3),$$

which may be made applicable to all vapors by the introduction of the specific heat K of the liquid. It then becomes

$$\text{Work}=JKD_1\left\{\tau_1-\tau_2\left(1+\log._e \frac{\tau_1}{\tau_1}\right)\right\}+$$
$$+\frac{\tau_1-\tau_2}{\tau_1}L_1+r(p_2-p_3) \quad . \quad . \quad (2)$$

The pressures p_2 and p_3 are the tensions of the vapor at the temperatures t_2 and t_3 in pounds on the square foot; t_3 being the temperature of the condenser, p_3 is the back pressure.

6. Equation (2) may be illustrated by the diagram, Plate I., Fig. 1. The ordinates represent pressures and the abscissas represent volumes. AO$=p_1$ the initial pressure. CG$=p_2$, the final pressure. HG and KO represent p_3, the back pressure. Equation (2) is an expression for the work represented by ABCHK. If the final and back pressures become equal, equation (2) becomes

$$W=JKD_1\left\{\tau_1-\tau_2\left(1+\log._e \frac{\tau_1}{\tau_2}\right)\right\}+$$
$$+\frac{\tau_1-\tau_2}{\tau_1}L_1 \quad . \quad . \quad (3)$$

and the diagram representing the work is ABCE.

If an amount of heat, L_1, is added to a fluid at the temperature τ_1, and then worked in the cycle of Carnot between the temperatures τ_1 and τ_2 the amount of heat changed into work is $\frac{\tau_1-\tau_2}{\tau_1}L_1$, as shown by Rankine, Clausius, and other writers. From this it follows that the work represented by ABCD is equal to $\frac{\tau_1-\tau_2}{\tau_1}L_1$, and therefore the work of adiabatic compression in the cycle of Carnot is

$$JKD_1\left\{\tau_1-\tau_2\left(1+\log._e \frac{\tau_1}{\tau_2}\right)\right\}$$

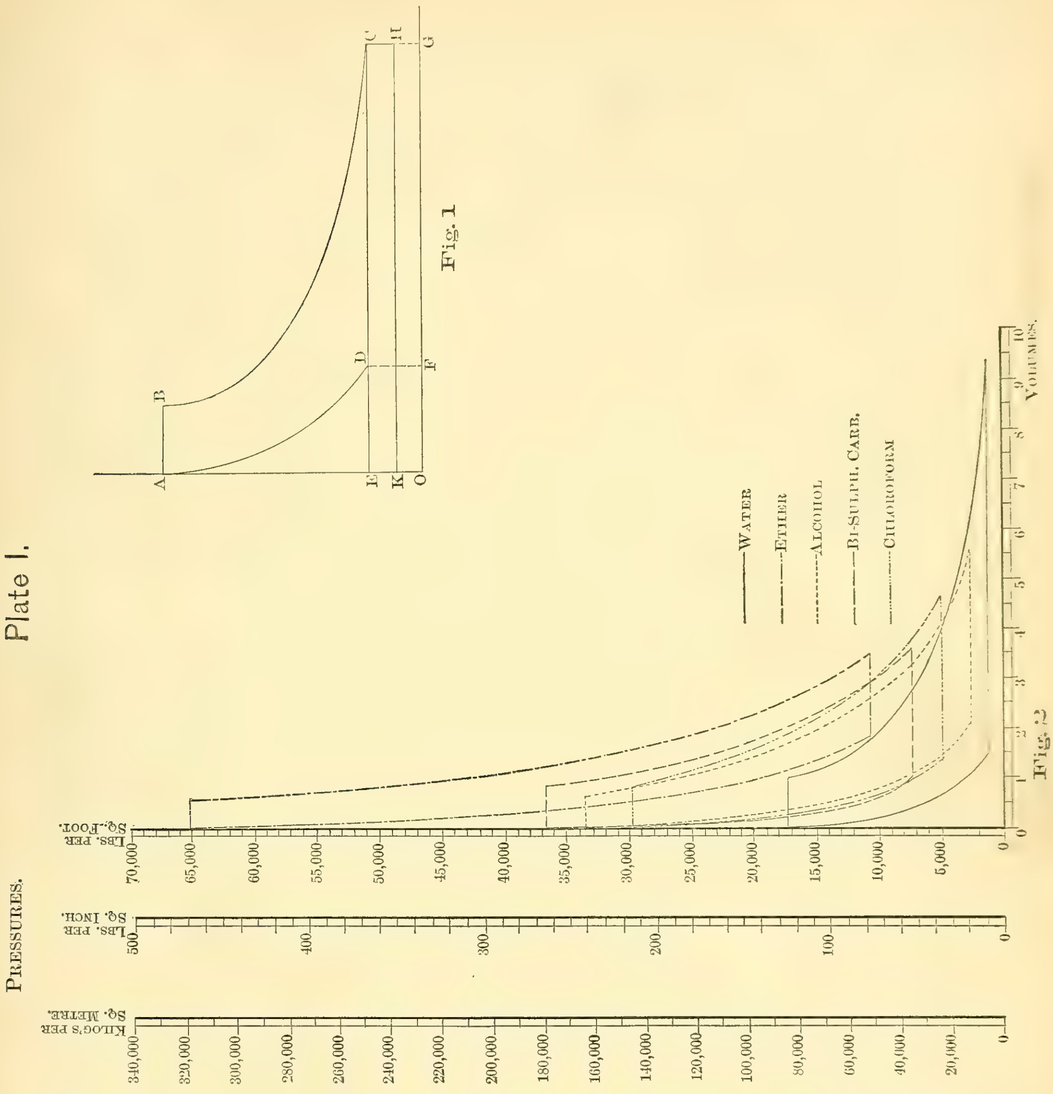
The total work of compression v^2, being the volume at the end of adiabatic expansion is

$$p_2v_2+JKD_1\left\{\tau_1-\tau_2\left(1+\log._e \frac{\tau_1}{\tau_2}\right)\right\}.$$

If the amount of vapor produced by the heat L_1 is not a unit volume, but is represented by v_1, the work of expansion in Carnot's cycle becomes

$$W=JKD_1v_1\left\{\tau_1-\tau_2\left(1+\log._e \frac{\tau_1}{\tau^2}\right)\right\}+$$
$$+\frac{\tau_1-\tau_2}{\tau_1}L_1+v_2p_2, \quad . \quad (4)$$

* Steam Engine, p. 388.
† Steam Engine, p. 388.



which is represented by ABC GO; the total work of compression is

$$JKD_1 v_1 \left\{ \tau_1 - \tau_2 \left(1 + \log_{\cdot e} \frac{\tau_1}{\tau_2} \right) \right\} + v_2\, p_2,$$

$v_2 p_2$ being represented by CGOE, and

$$JKD_1 v_1 \left\{ \tau_1 - \tau_2 \left(1 + \log_{\cdot e} \frac{\tau_1}{\tau_1} \right) \right\}, \text{ by ADE.}$$

The effective work is $\frac{\tau_1 - \tau_2}{\tau_1} L_1$.

7. As all the data available for the solution of this and the following cases are found in French and German works, and are consequently expressed in the metric system, we have adopted that system. The principal data and results however, are reduced to British units, and are given in both British and metric systems in a table at the end.

It is necessary to find the quantities required for substitution in equations (1) and (3), which data are:

$J = 424$ kilogrammeters.

τ_1 and τ_2, initial and final absolute temperatures on the Centigrade scale.

L_1 and L_2, latent heats of evaporation, in kilogrammeters, of one cu. me-

ter of saturated vapor at temperatures τ_1 and τ_2 respectively.

D_1 and D_2=weights in kilograms of one cubic meter of saturated vapor at temperatures τ_1 and τ_2 respectively.

= t ensions, in kilograms on the square meter, of the vapors at the temperatures τ_1 and τ_2.

K=mean specific heat of the liquid between the temperatures τ_1 and τ_2.

8. The initial and final temperatures chosen are

$$t_1=172° \text{ C. and } t_2=90° \text{ C., or}$$
$$T_1=445° \text{ C. and } T_2=363° \text{C.}$$

The pressures corresponding to these temperatures were taken either directly, or by interpolation, from tables given in Vol. II. of Regnault's "*Experiences*" whenever it was possible. When, however, owing to the limited range of temperatures given in these tables, this was impossible, the following formula given by Wüllner, "*Lehre von der Warme*," p. 617, was resorted to—

$$\log. S=a+b\alpha^t+c\beta^t \quad . \quad . \quad . \quad (5)$$

in which a, b, c, α and β are constants, t the temperature on the Centigrade scale, and S the pressure in millimeters of mercury.

For greater convenience of calculation Wüllner puts the constants in the following form:

	a	Sign of $b\alpha^t$	log. $b\alpha^t$
Alcohol	5.4562028	–	.6390301–.0029143 t
Ether	5.0286298	–	.4414317–.0031223 t
Bi-sulph. of carb.	5.4011662	–	.4918860–.0022372 t
Chlorof'm	5.2253893	–	.5219943–.0025856 t

	Sign of $c\beta^t$	log. $c\beta^t$
Alcohol	+	.5050675–3–.0590515t
Ether	+	.6512970–4+.0145775t
Bi-sulph. of carb.	–	.2799632–1–.0119062t
Chloroform	–	.0888717–1–.0131824t

The tensions for vapor of water were taken from a table of Regnault's results given by Wüllner on p. 610 of "*Lehre von der Warme.*"

The tensions found as just explained are

	S_1.	p_1.
Water	6,214.6	84,518
Alcohol	12,103	164,600
Ether	23,458	318,970
Bi-sulph. of carb	13,179	179,230
Chloroform	10,715	145,720

S_1 representing the tensions in millimeters of mercury, and p_1 the same tensions in kilograms on the square meter.

9. We now wish to find D, the weight in kilograms of a cubic meter of saturated vapor at the temperature t.

On page 668, in his "*Lehre von der Warme*," Wüllner gives, as the result of the work of Herwig on the density of saturated vapors, the formula

$$V_1=\frac{pv}{p_1\times .0595\sqrt{a+t}} \quad . \quad . \quad . \quad (6)$$

in which V_1=volume in cubic meters of one kilogram of saturated vapor at the absolute temperature $a+t$; p_1=tension of the vapor in millimeters of mercury at that temperature; while p and v represent the pressure and volume that the vapor would have at that temperature if it obeyed Marriott's law. If we suppose the vapor far enough removed from the point of saturation to act as a perfect gas, the following law holds good:—

$$pv=p_0v_0(1+\alpha t)=\alpha p_0V_0(a+t),$$

$a+t$ being the absolute temperature corresponding to the temperature t, and V_0 the volume of a unit weight of vapor under pressure p_0 at temperature 0° Centigrade. If we let V_0' represent the volume of a unit weight of air under the same pressure and at the same temperature, the density of the vapor referred to air is

$$\delta=\frac{V_0'}{V_0} \therefore V_0=\frac{V_0'}{\delta}.$$

Making this substitution, the product pv becomes

$$pv=\frac{\alpha p_0V_0'(a+t)}{\delta} \quad . \quad . \quad . \quad (7)$$

For air, if p_0=760 m. m., V_0'=.77339 cu. meters. For perfect gases α=.00366. Substituting in (7) we have

$$pv=\frac{.00366\times760\times.77339\times(a+t)}{\delta},$$

which being substituted in (6) gives

$$V_1=\frac{.00366\times760\times.77339\times\sqrt{a+t}}{p_1\delta\times.0595}$$

Reducing we get

$$V_1=\frac{36.2\sqrt{a+t}}{p_1\delta} \quad . \quad . \quad . \quad . \quad (8)$$

in which p_1 is the tension of the saturated vapor at temperature t_1, and V_1 is the volume in cubic meters occupied by one kilogram of vapor at the same temperature.

It follows that the weight D_1 in kilograms of a cubic meter of saturated vapor is

$$D_1=\frac{1}{V_1}=\frac{p_1\delta}{36.2\sqrt{a+t}} \quad . \quad . \quad . \quad (9)$$

The densities, δ, of the several vapors, referred to that of air, are given by Clausius in his "Mechanical Theory of Heat," page 59* and are

	δ.
Water	.6219
Alcohol	1.5819
Ether	2.5573
Bi-sulph. of carb	2.6258
Chloroform	4.1244

Substituting in equation (9) we find D_1 and D_2 corresponding to the temperatures $t_1=172°$ C. and $t_2=90°$ C.

	D_1.	D_2.
Water	5.07	.467
Alcohol	25.18	2.74
Ether	78.66	14.47
Bi-sulph. of carb	45.37	9.98
Chloroform	57.84	11.13

10. The latent heats, L_1 and L_2, of evaporation per cubic meter of saturated vapor in kilogrammeters at temperatures t_1 and t_2 are now to be found.

On page 640 of "*Lehre von der Warme*," Wüllner gives the formula

$$\lambda=a+bt+ct^2 \quad . \quad . \quad . \quad . \quad (10)$$

for the latent heat of evaporation per kilogram at temperature t.

The constants for ether, bi-sulphide of carbon and chloroform are

	a.	b.	c.
Ether	94	−.07901	−.0008514
Bi-sulph. of carb	90	−.08922	−.0004938
Chloroform	67	−.09485	−.0000507

For alcohol, a table of latent heats for every ten degrees up to 150° C. is given; and for water a similar table up to 194.8° C. (See p. 635 "*L. v. d. W.*")

From formula (10), in which the latent heats are given in calories, and from the tables we get the results:

	λ_1.	λ_2.
Water	483	542
Alcohol	159	206
Ether	55.2	80
Bi-sulph. of carb	60.1	78
Chloroform	49.2	58.1

By multiplying these quantities by Joule's equivalent, 424 k. g. m., and the products by D_1 and D_2 respectively, we get L_1 and L_2.

	L_1.	L_2.
Water	1,038,300	107,300
Alcohol	1,697,500	239,400
Ether	1,841,000	482,800
Bi-sulph. of carb	1,156,100	330,200
Chloroform	1,206,600	274,200

11. To find the mean specific heat K between t_1 and t_2, we take the average of the specific heats at those temperatures.

On page 485, "*L. v. d. W.*" is given the formula

$$K_t=A+2Bt+3Ct^2 \quad . \quad . \quad . \quad . \quad (11)$$

for the specific heat at the temperature t. The specific heat of water is unity; the values of the constants for the other vapors are

	A.	B.	C.
Alcohol	.54754	.0011218	.000002206
Ether	.52901	.0002958	0
Bi-sulph. of carb	.23523	.0000815	0
Chloroform	.23235	.0000507	0

The mean specific heats between the temperatures 172° and 90° C. found as just explained are:

* Browne's Translation, London, 1879.

	K.
Water	1
Alcohol	.966
Ether	.607
Bi-sulph. of carb	.257
Chloroform	.246

12. Having found the data necessary for substitution in equation (1), we may find the ratios of expansion. They are

Water	$r=9.37$
Alcohol	$r=8.97$
Ether	$r=6.11$
Bi-sulph. of carb	$r=3.96$
Chloroform	$r=5.22$

We may now discuss the action of each of the five vapors in working 1038300 k. g. m. of heat between the temperatures t_1 and t_2.

The total work of expansion is given by formula (4), §6, and the work of compression by the next formula. All the quantities required for substitution in those formulas are known except v_1 and v_2; but $v_2=rv_1$; therefore we have only to find v_1. The amount of heat required to evaporate one cubic meter of vapor at temperature t_1 being given in §10, we may find the volume of each vapor generated by 1,038,300 k. g. m. by dividing 1,038,300 by the value of L_1 in §10.

$$v_1=\frac{1{,}038{,}300}{L_1} \quad . \quad . \quad . \quad . \quad (12)$$

	v_1.
Water	1
Alcohol	.6116
Ether	.5640
Bi-sulph. of carb	.8980
Chloroform	.8615

The amount of fluid used is v_1D_1 kilogs. Then we have (§6) Work of expansion=

$$JKD_1v_1\left\{\tau_1-\tau_2\left(1+\log._e\frac{\tau_1}{\tau_2}\right)\right\}+$$
$$+\frac{\tau_1-\tau_2}{\tau_1}L_1+v_2p_2$$

Work of compression=

$$JKD_1v_1\left\{\tau_1-\tau_2\left(1+\log._e\frac{\tau_1}{\tau_2}\right)\right\}+v_3p_2$$

Effective work=

$$\frac{\tau_1-\tau_2}{\tau_1}L_1$$

Substituting, we have

	Work of Expansion.	Work of Compression
Water	274,767	83,408
Alcohol	331,322	139,863
Ether	466,740	275,381
Bi-sulph. of carb	354,120	162,761
Chloroform	347,474	156,115

	Effect've Work.	Heat Used.	Efficiency.
Water	191,359	1,038,300	18.43 %
Alcohol	191,359	1,038,300	18.43 %
Ether	191,359	1,638,300	18.43 %
Bi-sulph. of carb.	191,359	1,038,300	18 43 %
Chloroform	191,359	1,038,300	18.43 %

13. In the preceding, we have shown how the work of expansion and that of compression may vary greatly and still leave the effective work constant.

To show more clearly the action of the various vapors working in this cycle, we shall draw a diagram of Carnot's cycle for each case. To do this, it is necessary to find at least two more points in the curve of expansion, and the point at which adiabatic compression begins.

To find the points in the curve of expansion, we assume two temperatures, t_4 and t_5 between t_1 and t_2, and find the corresponding volumes and pressures.

If we represent by r_4 and r_5 the ratios of expansion corresponding to the absolute temperatures t_4 and t_5, formula (1) for the ratio of expansion becomes

$$r_4=\frac{\tau_4}{L_4}\left(JKD_1\log.\ \frac{\tau_1}{\tau_2}+\frac{L_1}{\tau_1}\right)$$

in which L_4 and L_5 have their original signification. As $L_1=D\times J\times\lambda$, we may make this formula more convenient in use by substituting for L_1 and L_4 their values. The formula then becomes

$$r_4=\frac{\tau_4}{\lambda_4D_4}\left(KD_1\log._e\frac{\tau_1}{\tau_4}+\frac{\lambda_1D_1}{\tau_1}\right) \quad (13)$$

In order to find r_4 and r_5 we need λ_4, λ_5, D_4, D_5, K, τ_4, and τ_5; and to find D_4 D_5 we need p_4 and p_5.

τ_4 and τ_5 were taken respectively as 418° and 393° C.

K is the same as before.

λ is found as before in § 10, D as in § 9, p as in § 8, p being identical with p_1 of that article.

These quantities are

	p_4. m. m.	p_5. m. m.	λ_4.	λ_5.	D_4.	D_5.	K.	D_1.
Water	3,125	1,491	504.7	522.6	2.63	1.29	1	5.07
Alcohol	6,485	3,232	173.1	186.8	13.87	7.16	.966	25.18
Ether	12,957	7,719	64.6	72.3	44.82	27.50	.607	78.66
Bi-sulph. of carb	8,237	5,149	66.7	72.2	29.26	18.90	.237	45.37
Chloroform	6,618	3,926	52.2	54.9	36.85	22.50	.246	57.84

Substituting these values we get r_4 and r_5 the following:

	r_4.	$v_4 = r_4 v_1$.	r_5.	$v_5 = r_5 v_1$.
Water	1.83	1.83	3.51	3.51
Alcohol	1.83	1.12	3 54	2.17
Ether	1.85	1.04	3.11	1.75
Bi-sulph. of carb	1.47	1.32	2.18	1.95
Chloroform	1.58	1.36	2.60	2.24

14. It is now necessary to find the point at which adiabatic compression begins. This is done as follows:—At the point D, at which adiabatic compression begins, the mixture of liquid and vapor has the pressure p_2 and volume v_6. This mixture is then made by compression to assume a volume, 0*, under pressure p_1 and at temperature t_1, when it becomes reduced entirely to the liquid state. If the fluid now expand adiabatically until it takes the volume v_6=ED under pressure p_2, it will perform the work represented by ADF OA, which may be divided into two parts,

$$\text{EDFO} = p_2\, v_6, \text{ and ADE} = \text{JKD}_1 v_1 \left\{ \tau_1 - \tau_2 \left(1 + \log._e \frac{\tau_1}{\tau_2}\right) \right\}$$

We have assumed, for convenience of illustration, that the fluid is expanding instead of being compressed. This we may do without error, as the operations of expansion are exactly those of compression reversed.

At the point A, Plate I., Fig. 1, we have $D_1 v_1$ kilograms of liquid at temperature t_1, at the point D the same weight of liquid and vapor is under pressure p_2 at temperature t_2 and occupies the volume v_6. Since this expansion is adiabatic, the difference between the sensible heats existing at A and D has been entirely converted, either into work, or into latent heat of evaporation. This amount of heat is

* The volume occupied by the fluid in the liquid state is so small in comparision with that assumed by the vapor that it may be considered as equal to 0.

$$H = D_1 \times v_1 \times K \times (t_1 - t_2) \times 424$$

expressed in kilogrammeters.

The work done during expansion is

$$\text{ADFOE} = \text{JKD}_1 v_1 \left\{ \tau_1 - \tau_2 \left(1 + \log._e \frac{\tau_1}{\tau_2}\right) \right\} + p_2\, v_6.$$

The amount of sensible heat that has become latent is that required to evaporate $D_2\, v_6$ kilogs. of vapor.

As the evaporation takes place not at any particular temperature, but throughout the entire range from t_1 to t_2, we have taken as the latent heat of evaporation the average of the latent heats at the temperatures t_1 and t_2, which per kilogram is $\frac{\lambda_1 + \lambda_2}{2}$. Hence the amount of heat which has become latent is, in kilogrammeters,

$$D_2\, v_6 \times \frac{\lambda_1 + \lambda_2}{2} + 424.$$

As all the sensible heat that has disappeared has been either changed into work or into latent heat, we may write the equation

$$D_1\, v_1\, K \times (\tau_1 - \tau_2) \times 424 =$$
$$\text{JKD}_1 v_1 \left\{ \tau_1 - \tau_2 \left(1 + \log._e \frac{\tau_1}{\tau_2}\right) \right\} +$$
$$+ p_2\, v_6 + D_2\, v_6 \frac{\lambda_1 + \lambda_2}{2} \times 424$$

It may be seen by inspection that all the quantities in this equation are known except v_6. We can therefore find v_6, and hence, D. Solving for v_6, we have

$$v_6 = \frac{D_1 v_1 K (t_1 - t_2) \times 424 - JKD_1 v_1 \left\{ \tau_1 - \tau_2 \left(1 + \log._e \frac{\tau_1}{\tau_2} \right) \right\}}{p_2 + D_2 \frac{\lambda_1 + \lambda_2}{2} \times 424}$$

15. The quantities necessary for the solution of this equation, those used in substituting in previous equations and the results of substitution, are given in the following tables in both metric and British units.

The diagrams showing the behavior of each of the vapors when worked in Carnot's cycle, are found in Fig. 2 of Plate 1.

TABLE I.

DATA AND RESULTS FOR CASE I.

METRIC UNITS.

Vapors.	t_1.	t_2.	t_4.	t_5.	τ_1.	τ_2.	τ_4.	τ_5.
	Cent.	Cent.	Cent.	Cent.	Cent.	Cent.	Cent.	Cent.
Water..	172	90	145	120	445	363	418	393
Alcohol.............	172	90	145	120	445	363	418	393
Ether...............	172	90	145	120	445	363	418	393
Carbon di-sulphide..	172	90	145	120	445	363	418	393
Chloroform.........	172	90	145	120	445	363	418	393

Vapors.	p_1.	p_2.	p_4.	p_5.	λ_1.	λ_2.	λ_4.	λ_5.
	Kgms on sq.mets.	Kgms on sq. mets.	Kgms on sq. mets.	Kgms on sq. mets.	Calories.	Calories.	Calories.	Calories.
Water.......	84,518	7,043	42,500	20,278	483	542	504.7	522.6
Alcohol.............	164,600	16,170	87,829	43,955	159	206	173.1	186.8
Ether...............	318,970	53,013	176,215	104,978	55.2	80	64.6	72.3
Carbon di-sulphide..	179,230	35,618	112,023	70,026	60.1	78	66.7	72.2
Chloroform.........	145,720	25,337	90,005	53,394	49.2	58.1	52.2	54.9

Vapors.	D_1.	D_2.	D_4.	D_5.	r.	r_4.	r_5.	k.
	Kgms pr cu. met.	Kgms pr cu. met.	Kgms pr cu. met.	Kgms pr cu. met.				
Water....	5.07	.467	2.63	1.29	9.37	1.83	3.57	1
Alcohol.............	25.18	2.74	13.87	7.16	8.97	1.83	3.54	.966
Ether...............	78.66	14.47	44.82	27.50	6.11	1.85	3.11	.607
Carbon di-sulphide..	45.37	9.98	29.26	18.90	3.96	1.47	2.18	.257
Chloroform.........	57.84	11.13	36.85	22.50	5.22	1.58	2.60	.246

Vapors.	v_1.	v_2.	v_4.	v_5.	Work of Expansion	Work of Compression	Effective Work.	Heat Used.	Efficiency
	cubic mets.	cu. m's.	cu. m's.	cu. m's.	Kilogram-meters.	Kilogram-meters.	Kilogram-meters.	Kilogram-meters.	Per cent.
Water............	1	9.37	1.83	3.57	274,767	83,408	191,359	1,038,300	18.43
Alcohol...........	.6116	5.48	1.12	2.17	331,222	139,863	191,359	1,038,300	18.43
Ether.............	.5640	3.45	1.04	1.75	466,740	275,381	191,359	1,038,300	18.43
Carbon di-sulphide	.8980	3.56	1.32	1.95	354,120	162,761	191,359	1,038,300	18.43
Chloroform.......	.8615	4.50	1.36	2.24	347,474	156,115	191,359	1,038,300	18.43

TABLE II.

DATA AND RESULTS FOR CASE I.

BRITISH UNITS.

Vapors.	t_1	t_2	t_4	t_5	τ_1	τ_2	τ_4	τ_5	p_1
	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Lbs. on sq. foot.
Water	342	194	193	248	803.2	655.2	754.2	709.2	17,310
Alcohol	342	194	193	248	803.2	655.2	754.2	709.2	33,712
Ether	342	194	193	248	803.2	655.2	754.2	709.2	65,328
Carbon di-sulphide.	342	194	193	248	803.2	655.2	754.3	709.2	36,708
Chloroform	342	194	193	248	803.2	655.2	754.2	709.2	29,845

Vapors.	p_2	p_4	p_5	λ_1	λ_2	λ_4	λ_5	D_1	D_2
	Lbs. on sq. foot.	Lbs. on sq. foot.	Lbs. on sq. foot.	Thermal units.	Ther. units.	Ther. units.	Ther. units.	Lbs. per cu. foot.	Lbs. per cu. foot.
Water	1,442	8,705	4,153	869.4	975.6	908.5	940.7	.317	.029
Alcohol	3,312	17,989	9,003	286.2	370.8	311.6	336.2	1.572	.171
Ether	10,858	36,090	21,501	99.4	144	116.3	130.1	4.911	.903
Carbon di-sulphide.	7,295	22,943	14,342	108.2	140.4	120.1	130.0	2.832	.623
Chloroform	5,189	18,433	10,936	92.6	104.6	94.0	98.8	3.611	.695

Vapors.	D_4	D_5	r	r_4	r_5	v_1	v_2	v_4	v_5
	Lbs. per cu. foot.	Lbs. per cu. foot.				Cu. feet.	Cu. feet.	Cu. feet.	Cu. feet.
Water	.164	.081	9.37	1.83	3.51	1	9.37	1.83	3.51
Alcohol	.866	.447	8.97	1.83	3.54	.6116	5.48	1.12	2.17
Ether	2.798	1.717	6.11	1.85	3.11	.5640	3.45	1.04	1.75
Carbon di-sulphide.	1.827	1.180	3.96	1.47	2.18	.8980	3.56	1.32	1.95
Chloroform	2.301	1.405	5.22	1.58	2.60	.8615	4.56	1.36	2.24

Vapors.	K	Work of Expansion.	Work of Compression	Effective Work.	Heat used.	Efficiency.
		Kilog'meters	Kilog'meters	Kilog'meters	Kilog'meters	
Water	1	56,275	17,083	39,192	212,654	18.43 %
Alcohol	.966	67,857	28,645	39,192	212,654	18.43 %
Ether	.607	95,593	56,401	39,192	212,654	18.43 %
Carbon di-sulphide.	.257	72,527	33,335	39,192	212,654	18.43 %
Chloroform	.246	71,166	31,974	39,192	212,654	18.43 %

CASE II.

16. The object of this case is to determine which of the fluids—water, alcohol, ether, bi-sulphide of carbon and chloroform—would be most suitable as the working fluid of an engine, if worked as saturated vapor in a non-conducting cylinder between the limits of pressure usually employed in the steam engine.

Rankine's formulas, eqs. (1) and (2), for ratio of expansion and work done are applicable to this case, and we must now find the quantities necessary for substitution. These quantities, together with a brief statement of how they are obtained, will be given, and, at the end of this division, the necessary data and results will be tabulated in both metric and British units.

17. The pressures assumed are $p_1 = 6214.6$ mm. of mercury, or 84518 kilograms per square meter, $p_2 = 517.9$ mm. of mercury, or 7403 kilograms per square meter. The temperatures corresponding to this pressure are found in tables given by Regnault in his "*Expériences*," and are—

	t_1.	t_2.	τ_1.	τ_2.
Water	172	90	445	363
Alcohol	144	69	417	342
Ether	110	$24\frac{1}{2}$	383	$297\frac{1}{2}$
Bi-sulph. of carb	130	35	403	308
Chloroform	141	49	414	322

To find D_1, the weight in kilograms per cubic meter of saturated vapor, we have formula (9)—

$$D_1 = \frac{p_1 \delta}{36.2\sqrt{a+t}}$$

The values of δ are given in §9. Substituting in the formula, we get,

	D_1.	D_2.
Water	5.07	.467
Alcohol	13.36	1.23
Ether	22.42	2.12
Bi-sulph. of carb	22.41	2.14
Chloroform	34.78	3.29

The latent heats of evaporation, L_1 and L_2, per cubic meter of vapor at temperature t_1 and t_2, expressed in kilogram-meters are found as in §10, and are—

	L_1.	L_2.
Water	1,038,300	107,300
Alcohol	985,600	115,256
Ether	713,000	82,337
Bi-sulph. of carb	665,100	78,305
Chloroform	775,600	86,766

The mean specific heats are found as in §11, but will differ from those previously found, as the ranges of temperature are not the same. They are—

	K.
Water	1
Alcohol	.871
Ether	.569
Bi-sulp. of carb	.249
Chloroform	.242

It is to be remembered that t_1 and t_2 have different values for each of the vapors.

18. Having now all the data necessary for substitution in formula (1),

$$r = \frac{\tau_2}{L_2}\left(JKD_1 \log._e \frac{\tau_1}{\tau_2} + \frac{L_1}{\tau_1}\right)$$

we may find the ratios of expansion, which are—

	$r = rv_1 = v_2$.
Water	9.37
Alcohol	9.92
Ether	12.06
Bi-sulph. of carb	9.00
Chloroform	10.29

To find the work done we substitute in formula (2),

$$W = \text{work} = JKD_1 \left\{ \tau_1 - \tau_2\left(1 + \log_e \frac{\tau_1}{\tau_2}\right) \right\} + \\ + \frac{\tau_1 - \tau_2}{\tau_1} L_1 + r\,(p_2 - p_3)$$

To this substitution, we have all the quantities except p_3, the back pressure, which is determined by the temperature of the condenser. As the temperature of the condenser cannot easily be kept lower than 104° Fahr., or 40° Centigrade, we have assumed that to be its temperature, and p_3 must, in each case, be the tension of the vapor corresponding to this temperature.

From Regnault's tables we have,

	p_3 (m.m. of Mercury).	p_3 (kilogs. per sq. meter).
Water	55	748
Alcohol	134	1,825
Ether	907	12,335
Bi-sulph. of carb	618	8,405
Chloroform	366	4,973

Making the proper substitutions we obtain for work done:

Water	267,705	kilogrammeters.
Alcohol	264,617	"
Ether	151,643	"
Bi-sulph. of carb.	173,553	"
Chloroform	232,456	"

19. To determine the *efficiency of fluid* of the several vapors, we must first find the heat expended per cubic meter of vapor at temperature t_1. As the feed for the boiler is taken from the surface-condenser, its temperature is t_3. The heat used is then the amount necessary to raise D_1 kilograms of liquid from temperature t_3 to t_1, and to evaporate them at that temperature.

20. This is most easily found by calculating the total heat of evaporation from 0° C. to t_1, and subtracting from this quantity the heat required to raise the liquid from 0° to t_3.

The total heat of evaporation per kilogram from 0° to t is given by the formula

$$Q=A+Bt+Ct^2$$

(p. 640, Wüllner's "*L. v. d. W.*").

The constants for ether, bi-sulphide of carbon and chloroform, are—

	A.	B.	C.
Ether	94	.4500	−.0005555
Bi-sulph. of carb.	90	.14601	−.0004123
Chloroform	67	.1375	0

The value for alcohol was determined from the table on page 641, "*L. v. d. W.*" by interpolation, and that for water was determined by the same method from the table on p. 635 of the same work.

The total heats of evaporation at temperature t_1 per kilogram, expressed in calories, are—

	t_1.	Q_1.
Water	172	659.0
Alcohol	144	282.5
Ether	110	136.8
Bi-sulph. of carb.	130	102.0
Chloroform	141	86.4

The same quantities for D_1 kilogs. of vapor, expressed in kilogrammeters, are given by

$$H_1=424 \times D_1 \times Q_1,$$

and are

	H_1.
Water	1,416,639
Alcohol	1,600,261
Ether	1,300,431.7
Bi-sulph. of carb.	969,188
Chloroform	1,274,117

The amount of heat, h_3, expressed in mechanical units, necessary to raise the temperature of the liquid from 0 to t_3 is found by multiplying the mean specific heat for that range of temperature by (t_3-0), D_1 and 424.

On page 483, "*L. v. d. W.*," the following formula is given for the mean specific heat between 0 and t:

$$C_t = A+Bt+Ct^2,$$

in which A, B and C have the values given in §11.

Hence,

$$h_3=C_t \times D_1 \times 40 \times 424.$$

The values of h_3 are

	h_3.
Water	86,000
Alcohol	135,054
Ether	205,710
Bi-sulph of carb.	90,459
Chloroform	138,032

The efficiency of fluid is the work divided by the mechanical equivalent of the heat used, or

$$E=\frac{W}{H_1-h_3}=\frac{W}{H}$$

	$H=H_1-h_3$.	E.
Water	1,330,639	20.12 %
Alcohol	1,465,207	18.06 %
Ether	1,094,722	13.85 %
Bi-sulph. of carb.	878,729	19.75 %
Chloroform	1,136,085	20.46 %

These efficiencies are different, as they should be, the fluids being worked through different ranges of temperature.

To show the relation between the power developed per stroke, and the size of cylinder for each of these vapors, the power developed in a cylinder one cubic meter in volume is calculated. As, in the problem just discussed, the initial volume of vapor was one cubic meter, the volume of cylinder, v_2, required for its working is r cu. meters. It thus follows that, in a cylinder of one cubic meter capacity, the work done would be $\frac{W}{r}$. The values of this ratio are—

	$\frac{W}{r}$
Water	28,570
Alcohol	26,675
Ether	12,574
Bi-sulph. of carb	19,284
Chloroform	22,590

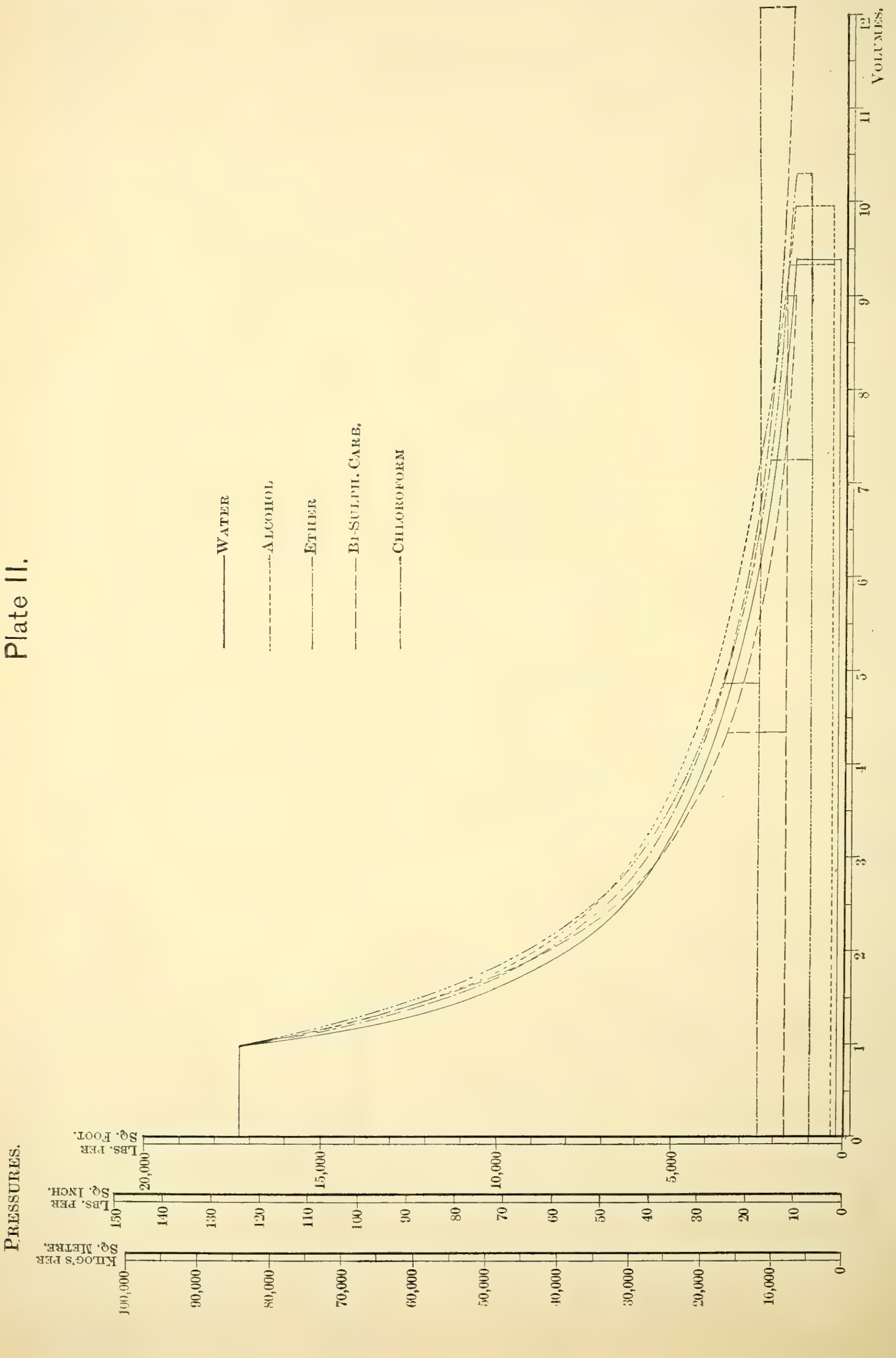
To render the comparison of these numbers easier, the ratio of each to that of water is taken. These ratios give the relative powers developed in cylinders of the same size; their reciprocals give the relative volumes of cylinder required to produce the same power.

	Ratio.	Reciprocal.
Water	1.	1.
Alcohol	.934	1.071
Ether	.440	2.275
Bi-sulph. of carb.	.676	1.480
Chloroform	.791	1.264

From the above, it is seen that steam requires the smallest cylinder to produce a given power, if worked between the limits of pressure we have taken. It is also more efficient than any of the vapors, except chloroform. The losses due

to the larger cylinder necessary to work chloroform would probably bring down its efficiency in practice, at least to that of steam if not lower. So far, then, it would seem that steam is the best fluid to use in heat engines.

23. As a matter of interest, we have constructed theoretical indicator cards for the vapors studied, showing how expansion would take place in a heat-engine cylinder. These cards are shown in Plate II. Two temperatures, t_4 and t_5,



were taken between t_1 and t_2, and the corresponding pressures found from tables in Regnault's "*Expériences*," or by the formula (5) of §8. The volumes were calculated by Rankine's formula for ratio of expansion, as modified in §13; the initial volume being unity, the formula becomes—

$$r_4 = \frac{\tau_4}{\lambda_4 D_4}\left(KD_1 \log._e \frac{\tau_1}{\tau_4} + \frac{\lambda_1 D_1}{\tau_1}\right)$$

λ_4 and λ_5 were calculated as in §10, and D_4 and D_5 as in §9. K is nearly the same as in §7.

In Tables III. and IV. are given, in both metric and British units, all the data necessary for this case, together with the results of substitution.

The final volume, $v_2 = rv_1$; but as $v_1 = 1$, $v_2 = r$; hence, v_2 and not r, is found in the tables.

24. Before giving the tables, we shall define the various quantities that appear in them.

METRIC UNITS.

τ_1, absolute initial temperature on the C. scale.

τ_2, absolute final temperature on same scale.

τ_4 and τ_5, absolute temperatures of intermediate points.

t_1, temperature on C. scale, corresponding to absolute temperature τ_1

t_3, temperature of condenser.

p, tension of vapor in kilogs. per sq. meter at temperature t.

λ, latent heat of evaporation in calories of 1 kilog. of vopor at temperature t.

L, latent heat of evaporation in k g.m. at temperature t of 1 cu. m. of vapor.

v, volume corresponding to ratio of expansion r.

w, work (in k.g.m.) done per cu. m. of vapor at temperature t_1.

H, total heat (in k. g.m.) used per cu. m. of vapor at temperature t.

F, kilograms used per H. P. per hour.

M, relative size of cylinder to produce the same power.

BRITISH UNITS.

τ_1, absolute initial temperature on the Fahr. scale.

τ_2, absolute final temperature on same scale.

τ_4 and τ_5, absolute temperatures of intermediate points.

t_1, temperature on F. scale corresponding to absolute temperature τ_1.

t_3, temperature of condenser.

p, tension of vapor in lbs. per square ft. at temperature t.

λ, latent heat of evaporation in British thermal units of 1 lb. of vapor at temperature t.

L, latent heat of evaporation of 1 cu. ft. of vapor in ft. lbs. at temperature t.

v, volume corresponding to ratio of expansion r.

w, work (in ft. lbs.) done per cu. ft. of vapor at temperature t_1.

H, total heat (in ft. lbs.) used per cu. ft. of vapor at temperature t.

F, lbs. used per H. P. per hour.

M, relative size of cylinder to produce the same power.

TABLE III.

DATA AND RESULTS IN CASE II.

METRIC UNITS.

Vapors.	τ_1	τ_2	τ_4	τ_5	t_1	t_3	D_1	D_4	D_5
Water............	445	363	418	393	172	40	5.07	2.63	1.29
Alcohol...........	417	342	393	353	144	40	13.36	3.86	1.90
Ether....	383	297.5	393	353	110	40	22.42	18.14	11.40
Bi-sulph. of carb...	403	308	393	353	130	40	22.41	12.50	7.80
Chloroform........	414	322	393	353	141	40	34.78	14.31	8.50

Vapors.	p_1	p_2	p_3	p_4	p_5	λ_1	λ_4	λ_5	K
Water............	84,518	7,043	748	42,500	20,278	483	504.7	522.6	1
Alcohol...	84,518	7,043	1,822	23,093	11,057	174	199.	213.	.871
Ether.............	84,518	7,043	12,335	67,361	41,113	75	77.6	82.2	.569
Bi-sulph. of carb...	84,518	7,043	8,405	45,220	27,649	70	76.1	79.7	.249
Chloroform........	84,518	7,043	4,978	33,021	25,894	52.6	57.	59.1	.242

Vapors.	L_1	L_2	v_2	v_4	v_5	W	H	E	M	F
Water	1,038,300	107,300	9.37	1.83	3.57	267,705	1,330,639	20.12 %	1	5.19
Alcohol	985,600	115,256	9.92	3.97	8.12	264,617	1,465,207	18.06 %	1.071	13.83
Ether	713,000	82,337	12.06	1.25	2.05	151,643	1,094,722	13.85 %	2.275	40.49
Bi-sulph. of carb.	665,100	78,305	9.00	1.87	3.06	173,553	878,729	19.75 %	1.480	35.46
Chloroform	775,600	86,766	10.29	2.68	4.66	232,456	1,136,085	20.46 %	1.264	40.97

Table IV.

Data and Results in Case II.

BRITISH UNITS.

Vapors.	τ_1	τ_2	τ_4	τ_5	t_1	t_3	D_1	D_4	D_5
Water	803	655	754	709	342	104	.317	.164	.081
Alcohol	752	617	673	637	291	104	.834	.241	.119
Ether	691	537	673	637	230	104	1.400	1.132	.712
Bi-sulph. of carb.	727	556	673	637	266	104	1.399	.780	.487
Chloroform	747	581	673	637	286	104	2.171	.893	.531

Vapors.	p_1	p_2	p_3	p_4	p_5	λ_1	λ_4	λ_5	K
Water	17,310	1,442	153	8,703	4,512	869.4	908.5	940.7	1
Alcohol	17,310	1,442	373	4,730	2,264	313.2	358.2	383.4	.871
Ether	17,310	1,442	2,526	13,796	8,420	135.0	139.7	148.0	.569
Bi-sulph. of carb.	17,310	1,442	1,721	9,261	5,663	126.0	137.0	143.5	.249
Chloroform	17,310	1,442	1,020	6,763	3,911	94.7	102.6	106.4	.242

Vapors.	L_1	L_2	v_2	v_4	v_5	W	H	E	M	F
Water	212,654	21,976	9.37	1.83	3.57	54,829	272,528	20.12 %	1	11.44
Alcohol	201,861	23,606	9.92	3.97	8.12	54,196	300,088	18.06 %	1.071	30.48
Ether	146,030	16,863	12.06	1.25	2.05	31,058	324,206	13.85 %	2.275	89.24
Bi-sulph. of carb.	136,219	16,038	9.00	1.87	3.06	35,545	179,973	19.75 %	1.480	78.15
Chloroform	158,851	17,771	10.29	2.68	4.66	47,609	232,685	20.46 %	1.264	90.30

25. From the indicator cards shown in Plate II., it may be seen that the ratios of expansion adopted in the last case are not most economical, especially in the cases of ether and bi-sulphate of carbon, in which cases the final pressure is lower than the back pressure, causing a loop in the expansion and exhaust lines. It has been found in steam-engine practice that it is not economical to expand down to the back pressure, the best results having been obtained when there is a difference between final and back pressure of from 7 to 10 lbs. on the square inch. It is probable that the best practical results, in the cases of the other vapors, would be obtained by producing a similar difference between final and back pressure. This assumption suggests a modification of Case II., which is given as Case III.

Case III.

26. In this case we have taken the same initial pressures as in the last, but have determined the final pressure by adding a nearly constant quantity to the back pressure, which latter pressure is determined by the temperature of the condenser, 40° C.

The formulæ (1) and (2) used to find the ratio of expansion and work done are the same as used in the last case. The symbols having subscripts (1) and (3) are the same as in the preceding case, those quantities represented by symbols having (2) for a subscript must now be found.

The pressures p_2 and p_3 are given below in kilograms on the square meter.

	p_2.	p_3.
Water	7,043	748
Alcohol	7,358	1,828
Ether	17,190	12,335
Bi-sulph. of carb	15,844	8,405
Chloroform	10,214	4,978

The temperatures t_2 corresponding to the pressures p_2, were found from the tables in Regnault's "*Expériences.*" D_2 is determined as in § 9; λ_2 as in § 10. With these data, and those of Case II., we may now find the values of the new ratio of expansion work done, and efficiency.

27. The data for this problem, together with the results obtained, are to be found in Tables V. and VI., in which the letters at the heads of the columns have the same signification as explained in § 24.

Table V.

Data and Results in Case III.

Metric System.

Vapors.	τ_1	τ_2	τ_4	τ_5	t_1	t_3	D_1	D_2	D_4	D_5
Water	445	363	418	393	172	40	5.07	.467	2.63	1.29
Alcohol	417	343	393	353	144	40	13.36	1.28	3.86	1.90
Ether	383	323	393	353	110	40	22.42	4.97	18.14	11.40
Carbon di-sulphide.	403	333	393	353	130	40	22.41	4.63	12.50	7.80
Chloroform	414	333	393	353	141	40	34.78	4.69	14.31	8.50

Vapors.	p_1	p_2	p_3	p_4	p_5	λ_1	λ_4	λ_5	K	L_1	L_2
Water	84,518	7,043	748	42,500	20,278	483	504.7	522.6	1	1,038,300	107,320
Alcohol	84,518	7,358	1,822	23,093	11,057	174	199	213	.871	985,600	119,941
Ether	84,518	17,190	12,335	67,361	41,113	75	77.6	82.2	.569	713,000	185,226
Carb. di-sulph.	84,518	15,844	8,405	45,220	27,649	70	76.1	79.7	.249	665,100	162,743
Chloroform..	84,518	10,214	4,978	33,021	25,894	52.6	57	59.1	.242	775,600	121,501

Vapors.	v_2	v_4	v_5	W	H	E	M
Water	9.37	1.83	3.57	267,705	1,330,639	20.12 %	1
Alcohol	9.51	3.97	8.12	262,614	1,465,207	17.92 %	1.035
Ether	4.85	1.25	2.05	162,869	1,094,722	14.88 %	.845
Carbon di-sulphide.	4.31	1.87	3.06	162,875	878,729	18.53 %	.756
Chloroform	7.24	2.68	4.66	219,200	1,136,084	19.29 %	.944

Table VI.

Data and results in Case III.

British units.

Vapors.	τ_1	τ_2	τ_4	τ_5	t_1	t_3	D_1	D_2	D_4	D_5
Water	803	655	754	709	342	104	.317	.029	.164	.081
Alcohol	752	619	673	637	291	104	.834	.080	.241	.119
Ether	691	583	673	637	230	104	1.400	.310	1.132	.712
Carbon di-sulphide	727	601	673	637	266	104	1.399	.289	.780	.487
Chloroform	747	601	673	637	286	104	2.171	.293	.893	.531

Vapors.	p_1	p_2	p_3	p_4	p_5	λ_1	λ_4	λ_5	K	L_1	L_2
Water	17,310	1,442	153	8,703	4,512	869.4	908.5	940.7	1	212,650	21,980
Alcohol	17,310	1,507	373	4,730	2,264	313.2	358.2	383.4	.871	201,861	24,565
Ether	17,310	3,524	2,526	13,796	8,420	135.0	139.7	148.0	.569	146,030	37,936
Carbon di-sulphide.	17,310	3,245	1,721	9,261	5,663	126.0	137.0	143.5	.249	136,219	33,331
Chloroform	17,310	2,092	1,020	6,763	3,911	94.7	102.6	106.4	.242	158,851	24,885

Vapors.	v_2	v_4	v_5	W	H	E	M
Water	9.37	1.83	3.51	54,829	1,330,639	20.12%	1
Alcohol	9.51	3.97	8.12	53,786	1,465,207	17.92%	1.035
Ether	4.85	1.25	2.05	33,357	1,094,722	14.88%	.845
Carbon di-sulphide	4.31	1.87	3.06	33,358	878,729	18.53%	.756
Chloroform	7.24	2.68	4.66	44,894	1,136,084	19.29%	.944

The indicator cards for this case are given in Plate II. They differ from those of Case II. only in the value of the ratio of expansion.

28. On comparison with Tables V. and VI. with Tables III. and IV., it will be seen that the efficiences in the latter case are greater than those in the former. It must be remembered, however, that in practice the losses by friction and condensation due to greater ratios of expansion in Problem II. will probably more than compensate for this small increase of useful work. Tables V. and VI. show, further, that steam has an advantage over all the other vapors in efficiency, and over alcohol in size of cylinder, while bi-sulphide of carbon excels all the others in the latter respect.

Case IV.

29. In Cases II. and III. we have considered the behavior of the several vapors in question when used as working fluids between the limits of pressure common in the modern steam engine. We shall now proceed to discuss, in Cases IV. and V., their behavior when worked between the limits of *temperature* used in the steam engine. The pressures assumed in the two preceding problems were $p_1=84{,}518$ kilograms per square meter, and $p_2=7{,}043$ kilograms per square meter. The temperatures of saturated water vapor under these pressures are $t_1=172°$ C., and $t_2=90°$ C. The temperature of the condenser is, as before, taken as 40° C., which is as low as it could be conveniently kept in practice.

The tensions of the saturated vapors of alcohol, ether, bisulphide of carbon, and chloroform, at these temperatures, have already been found in Case 1, § 8. In the same problem were also determined the values of D_1 and D_2, § 9; of λ_1 and λ_2, § 10; of K, § 11, and of r, § 12; while § 13 furnishes the value of D_4, D_5, λ_4, λ_5, p_4, p_5, r_4, and r_5.

Tables VII. and VIII. contain the data and results for this case; the corresponding indicator cards are found in Plate III. As the initial volume v_1, in the case under consideration, is one cubic meter, the final volumes, v_2, v_4 and v_5, will be different from the similar quantities in Case I., and will be numerically equal to the ratios of expansion r_1, r_4 and r_5. The letters at the head of the columns of the tables have the same signification as before explained.

Table VII.

Data and Results for Case IV.

METRIC UNITS.

Vapors.	t_1	t_2	t_3	t_4	t_5	τ_1	τ_2	τ_4	τ_5
Water	172	90	40	145	120	445	363	418	393
Alcohol	172	90	40	145	120	445	363	418	393
Ether	172	90	40	145	120	445	363	418	393
Carbon di-sulphide	172	90	40	145	120	445	363	418	393
Chloroform	172	90	40	145	120	445	363	418	393

Vapors.	p_1	p_2	p_3	p_4	p_5	λ_1	λ_2	λ_4	λ_5	K
Water..........	84,518	7,043	748	42,500	20,278	483	542	504.7	522.6	1
Alcohol..........	164,600	16,170	1,822	87,829	43.955	159	206	173.1	186.8	.966
Ether.............	318,970	53,013	12,335	176,215	104,978	55.2	80	64.6	72.3	.607
Carbon di-sulphide.	179,230	35,618	8,405	112,023	70,026	60.1	78	66.7	72.2	.257
Chloroform........	145,720	25,337	4,978	90,005	53,394	49.2	58.1	52.2	54 9	.246

Vapors.	D_1	D_2	D_4	D_5	v_2	v_4	v_5
Water............	5.07	.467	2.63	1.29	9·37	1.83	3.57
Alcohol..........	25.18	2.74	13.87	7.16	8.97	1.83	3.54
Ether.............	78.66	14.47	44.82	27.50	6.11	1.85	3.11
Carbon di-sulphide.	45.37	9.98	29.26	18.90	3.96	1.47	2.18
Chloroform........	57.84	11.13	36 85	22.50	5.22	1.58	2.60

Vapors.	W.	H.	E.	F.	M.
Water......................	267,705	1,330,639	20.12%	5.19	1
Alcohol......................	525,086	2,894,904	18.14%	13.13	.488
Ether......................	751,821	4,447,823	16.90%	28.64	.232
Carbon di-sulphide.........	360,878	1,798,275	20.07%	34.41	.314
Chloroform..	376,517	2,002,139	18.81%	42.06	.396

Table VIII.

Data and Results for Case IV.

BRITISH UNITS.

Vapors.	t_1	t_2	t_3	t_4	t_5	τ_1	τ_2	τ_4	τ_5
Water................	342	194	104	293	248	803.2	655.2	754.2	709.2
Alcohol........	342	194	104	293	248	803.2	655.2	754.2	709.2
Ether.............. ...	342	194	104	293	248	803.2	655.2	754.2	709.2
Carbon di-sulphide.....	342	194	104	293	248	803.2	655.2	754.2	709.2
Chloroform...........	342	194	104	293	248	803.2	655.2	754.2	709.2

Vapors.	p_1	p_2	p_3	p_4	p_5	λ_1	λ_2	λ_4	λ_5
Water......	17,310	1,442	153	8,705	4,153	869.4	975.6	908.5	940.7
Alcohol..............	33,712	3,312	373	17,989	9,003	286.2	370.8	311.6	336.2
Ether................	65,329	10,858	2,526	36,090	21,501	99.4	144	116.3	130.1
Carbon di-sulphide ..	36,708	7,295	1,721	22,943	14,343	108.2	140.4	120.1	130.0
Chloroform	29,845	5,189	1,020	18,433	10,936	92.6	104.6	94.0	98.8

Vapors.	K	D_1	D_2	D_4	D_5	v_2	v_4	v_5
Water	1	.317	.029	.164	.081	9.37	1.83	3.51
Alcohol............	.966	1.572	.171	.866	.447	8.97	1 83	3.54
Ether............ ..	.607	4.911	.903	2.798	1.717	6.11	1.85	3.11
Carbon di-sulphide ..	.257	2.832	.623	1.827	1.180	3.96	1.47	2.18
Chloroform	.246	3.611	.695	2.301	1.405	5.22	1.58	2.60

Vapors.	W.	H.	E.	F.	M.
Water.....................	54,829	272,528	20.12%	11.45	1
Alcohol....................	107,543	572,904	18.14%	28.94	.488
Ether.................. . .	153,980	910,954	16.90%	63.15	.232
Carbon di-sulphide	73,911	368,310	20.07%	75.87	.314
Chloroform...............	77,114	410,058	18.81%	92.72	.396

CASE V.

30. This problem bears the same relation to Case IV. that Case III. bears to Case II. In the preceding case we did not assume the most favorable practical conditions for the working of either of the fluids with the exception of water; hence, for the reasons already stated in § 25, we shall assume for our back pressure, p_2, the same values as were taken in Case III.

Tables IX. and X. contain a summary in Metric and British units of the data and results for this case. The corresponding theoretical indicator cards are shown in Plate III.

TABLE IX.

DATA AND RESULTS FOR CASE V.

METRIC UNITS.

Vapors.	t_1	t_2	t_3	t_4	t_5	τ_1	τ_2	τ_4
Water	172	90	40	145	120	445	363	418
Alcohol	172	70	40	145	120	445	343	418
Ether	172	50	40	145	120	445	323	418
Carbon di-sulphide	172	60	40	145	120	445	333	418
Chloroform	172	60	40	145	120	445	333	418

Vapors.	τ_5	p_1	p_2	p_3	p_4	p_5	λ_1	λ_2
Water	393	84,518	7,043	748	42,500	20,278	483	542
Alcohol	393	164,600	7,358	1,822	87,829	43,955	159	221
Ether	393	318,970	17,190	12,355	176,215	104,978	55.2	87.9
Carbon di-sulphide	393	179,230	15,844	8,405	112,023	70,026	60.1	82.9
Chloroform	393	145,720	10,214	4,978	90,005	53,394	49.2	61.1

Vapors.	λ_4	λ_5	K	D_1	D_2	D_4	D_5	v_2
Water	504.7	522.6	1	5.07	.467	2.63	1.29	9.37
Alcohol	173.1	186.8	.966	25.18	1.28	13.87	7.16	18.59
Ether	64.6	72.3	.607	78.66	4.97	44.82	27.50	18.53
Carbon di-sulphide	66.7	72.2	.257	45.37	4.63	29.26	18.90	8.25
Chloroform	52.2	54.9	.246	57.84	14.69	36.85	22.50	12.23

Vapors.	v_4	v_5	W	H	E	F	M
Water	1.83	3.57	267,705	1,330,639	20.12 %	5.19	1
Alcohol	1.83	3.54	622,978	2,894,904	21.52 %	11.07	.853
Ether	1.85	3.11	988,752	4,447,823	22.23 %	21.78	.535
Carbon di-sulphide	1.47	2.18	428,486	1,798,275	23.83 %	28.98	.550
Chloroform	1.58	2.60	462,834	2,002,139	23.12 %	34.21	.761

TABLE X.

DATA AND RESULTS FOR CASE V.

BRITISH UNITS.

Vapors.	t_1	t_2	t_3	t_4	t_5	τ_1	τ_2	τ_4
Water	342	194	104	293	248	803	655	754
Alcohol	342	158	104	293	248	803	655	754
Ether	342	122	104	293	248	803	655	754
Carbon di-sulphide	342	140	104	293	248	803	655	754
Chloroform	342	140	104	293	248	803	655	754

Vapors.	τ_5	p_1	p_2	p_3	p_4	p_5	λ_1	λ_2
Water	709	17,310	1,442	153	8,705	4,153	869.4	975.6
Alcohol	709	33,712	1,507	373	17,989	9,003	286.2	397.8
Ether	709	65,328	3,524	2,526	36,090	21,501	99.4	158.1
Carbon di-sulphide	709	36,708	3,245	1,721	22,943	14,342	108.2	141.2
Chloroform	709	29,845	2,092	1,020	18,433	10,936	92.6	130.0

Vapors.	λ_4	λ_5	K	D_1	D_2	D_4	D_5	v_2
Water	908.5	940.7	1	.317	.029	.164	.081	9.37
Alcohol	311.6	336.2	.966	1.572	.171	.866	.447	18.59
Ether	116.3	130.1	.607	4.911	.903	2.798	1.717	18.53
Carbon di-sulphide	120.1	130.0	.257	2.832	.623	1.827	1.180	8.25
Chloroform	94.0	98.8	.246	3.611	.695	2.301	1.405	12.23

Vapors.	v_4	v_5	W	H	E	F	M
Water	1.83	3.57	54,829	272,528	20.12 %	11.44	1
Alcohol	1.83	3.54	127,592	592,904	21.52 %	24.40	.853
Ether	1.85	3.11	202,506	910,954	22.23 %	48.02	.535
Carbon di-sulphide	1.47	2.18	87,758	368,310	23.83 %	63.88	.550
Chloroform	1.58	2.60	94,793	410,058	23.12 %	75.42	.761

Conclusions.

31. From Case I., which is simply an illustration of a well-known law of thermodynamics, it may be seen that the theoretical effective work obtainable from a given quantity of heat is, when Carnot's cycle and the same limits of temperature are employed, independent of the working fluid. At the same time, however, the component parts of the total work may vary very much, as is illustrated by the figures in Tables I. and II., or, more clearly, by the indicator diagrams, Plate I.

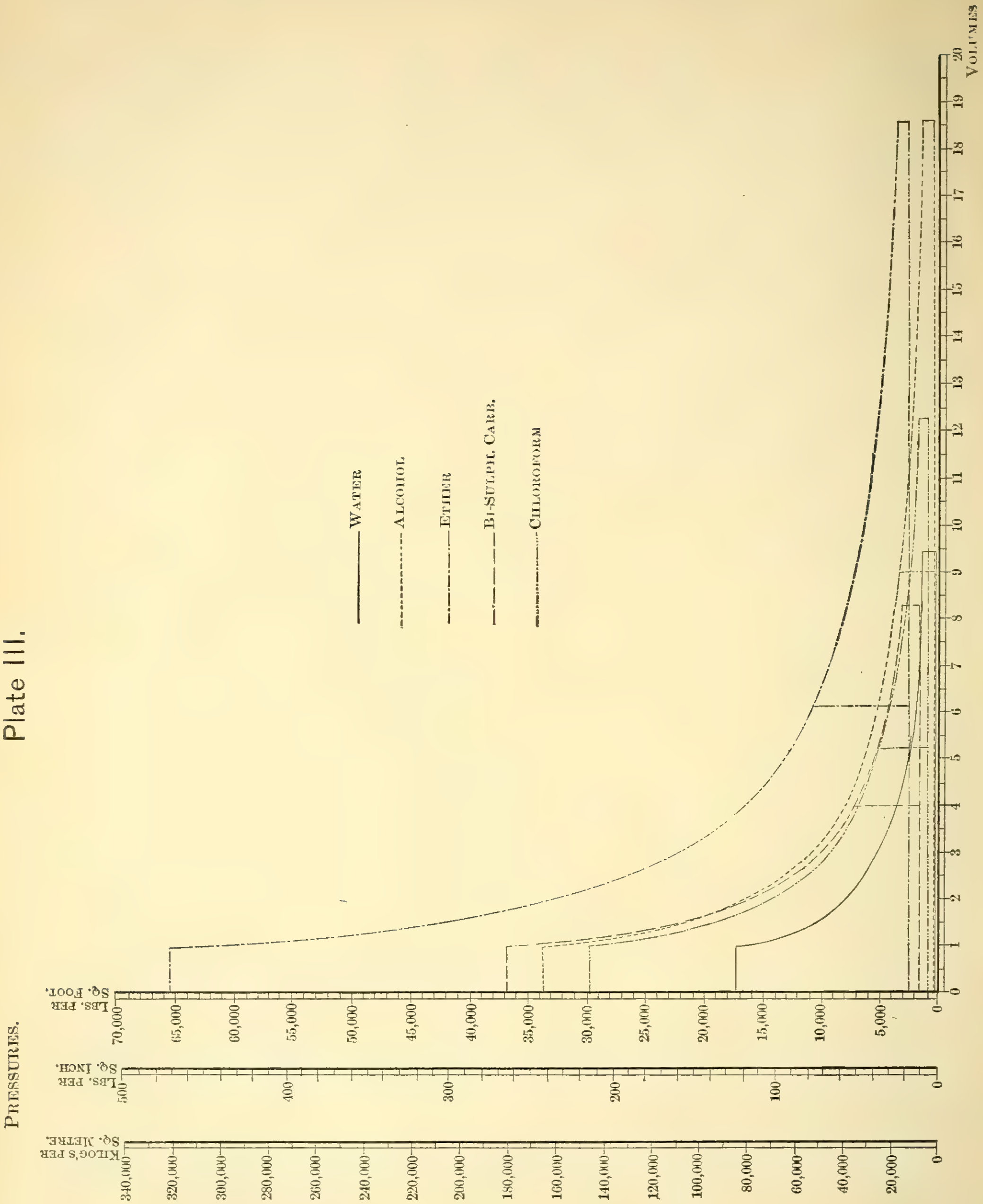
32. On comparing the efficiencies of the non-aqueous vapors in Case II. with the same quantities in Case III., we see that in every case, except that of ether, the figures are larger in the former than in the latter case. It would therefore seem, at first sight that the method we have taken of increasing the efficiency by reducing the ratio of expansion must fail. It must be remembered, however, that while, in the ideal case, expansion down to the back pressure is most efficient, there are certain practical considerations, such as condensation in the cylinder and friction of engine, which make a more limited ratio of expansion best. It is to this best ratio that we have tried to approximate in Case III., and hence the performance of engines built for working these fluids would agree more nearly with the results of this case than with those of Case II. It is for this reason that we consider the results in Case III. of more practical value than those of the case preceding it; and it may be seen that, *if we limit maximum pressure to that employed in the steam engine, steam is the most efficient fluid we can use.* The relative size of cylinder necessary to produce the same power which is represented by the letter M in Tables III. and IV., is smaller for steam than it is for the non-aqueous vapors when all have the same initial pressure.

Case V. resembles Case III. in having the same final pressures, but differs in having higher initial pressures in all cases except that of steam. This higher initial pressure, involving higher initial temperature, and consequently greater range of temperature, causes such an increase of efficiency of the non-aqueous vapors as to put them all above that of water, and to cause some doubt as to which would be the best working fluid, judged thermodynamically only.

As the most convenient method of deciding the question just raised, we may compare each of the vapors with that of water, showing their advantages and disadvantages.

The vapor of alcohol gives us 1.4 per

Plate III.



cent. more efficiency than steam, and requires a cylinder whose volume is only 0.853 of that of the steam cylinder to produce the same power. The disadvantages of alcohol are the high tension of the vapor, the great danger which arises from the ready inflammability of the hot liquid, and its cost.

The use of ether would give us a greater gain in efficiency (2.11 per cent.), and would require a still smaller cylinder (0.535 of that of steam), but it is open to the same objections as alcohol, and in a more marked degree.

The vapor of bi-sulphide of carbon gives a gain in efficiency of 3.71 per cent., and demands a cylinder 0.550 of that of steam. It, however, is not only open to

all the objections that have been stated against alcohol and ether, but it has two which are peculiar to itself, viz., its intensely disagreeable odor, and its power of rapidly corroding iron which comes alternately into contact with it and with the air.

The vapor of chloroform, which gives a gain of 3 per cent. efficiency, and requires a cylinder 0.761, the volume of that of steam, is not open to the objection of inflammability, but it has so high a cost that it is probably impossible that it can ever be used economically in competition with steam.

All the apparent advantages of the non-aqueous vapors may be gained in the steam engine by an increase of initial pressure; and, as the tendency of modern practice is in that direction, it seems certain that *none of the non-aqueous vapors will ever successfully compete with steam.*

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers.—*October 1st*, 1884.—Vice-President Wm. H. Paine in the chair. The following candidates were elected members: Burr Kellogg Field, Philadelphia, Pa; Charles Alfred Marshall, Johnstown, Pa.; Robert Imley Sloan, New York, N. Y.

Mr. H. Trueman Wood, Secretary of the Society of Arts, London, England, presented a short statement in reference to the International Inventions Exhibition, which it is proposed to hold in London during 1885. He expressed the desire of the management of the Exhibition that the engineers of America should know of this exhibition and aid in securing its success. It is one of the series of exhibitions which are in progress, that of last year being devoted to fisheries, and that of the present year to subjects connected with health and education. The Exhibition of 1885 will be devoted to apparatus, appliances, processes and products invented or brought into use since 1862. It is intended to illustrate industrial processes, and not to exhibit finished products unless required for full demonstration of a particular process. The Exhibition will be under the presidency of the Prince of Wales. The Chairman of the Executive Committee is Sir Frederick J. Bramwell, Vice-President Inst. C. E. Copies of a detailed prospectus were presented by Mr. Wood. The subject was referred to the Board of Direction for consideration.

The death on September 25th of Isaac Newton, M. Am. Soc. C. E., was announced.

Announcement was made that Messrs. L. B. Ward, E. B. Van Winkle and Amory Coffin had been appointed Censors to award the Norman Medal, and that Messrs. George S. Morison and D. Farrand Henry had been appointed on the committee to award the Rowland Prize.

A paper by F. P. Stearns, M. Am. Soc. C. E., "Experiments on the Flow of Water through a 48-inch pipe," was read. These Experiments were made on a pipe on the line of the Sudbury Conduit, used to carry water across a valley. The pipe was cast-iron, coated with Dr. Angus Smith's coal tar preparation.

ENGINEERING NOTES.

Monster Russian Bridge.—It is reported from Russia that the question is being agitated of connecting Cronstadt and Oranienbaum by a bridge at a cost of £2,400,000. The structure is to rest upon granite pillars fixed by the caisson method, each of them protected from the action of the waves during the prevalence of south-west wind by an angular wall-like guard of stone. The bridge will be about five miles in length, and it is expected to be completed by 1889. When finished—if it is ever finished—it will consist of two parts, a railway and a foot-bridge.

The Severn Tunnel was begun in 1873 and is now approaching completion. It passed under the Severn where it is $2\frac{1}{4}$ miles wide. The length of the line is $7\frac{1}{2}$ miles, $4\frac{1}{2}$ miles being in the tunnel under the Severn. It is made almost wholly in rocks of trias and coal measure formation. The lowest part of the line is at 60 feet depth at low water, and 100 feet at high water. The work has been flooded on several occasions, much water being met with throughout the construction. The quantity of water now being pumped is about 19,000 gallons per minute. Other pumps are being erected which will enable 41,000 gallons to be pumped. The tunnel will be for a double line of way, and will be lined throughout with vitrified bricks set in Portland cement.

The Forth Bridge.—The contract for the bridge has been let for £1,600,000. The total length of the viaduct is about one mile and a half; the clear headway under the center is 150 feet above high water. Operations began in January 1883, and already about £370,000 have been expended. The main piers are all started; the minor and end piers are in an advanced state. For the superstructure the iron has been delivered. In one of the Fife piers the drilling of the rock had to be abandoned, a timber and clay coffer dam being constructed. The difficulty in the shallow rock foundation at the Forth much resembled Stephenson's when building the Victoria Bridge, the contractors treating it in much the same way. Forty-two miles of plates are required for the tubular compression. Finally the proper method was hit upon, consisting in bending plates hot, giving them a straightening squeeze afterwards when cold. No important modification has been made in the design. One change was made in attaching the superstructure to masonry, which consisted in securing it to one of four cylindrical piers in each group, and permitting a certain amount of sliding on others. The whole weight of the structure on the piers will cause friction between the surfaces of the upper and lower bed plates sufficient to prevent movement except in rare cases. Experiments have

proved that 56 pounds per square inch would be the highest wind pressure likely to be encountered.

IRON AND STEEL NOTES.

Tempering Steel by Compression. — We have repeatedly alluded to the method brought forward in France by Clemandot for tempering steel by compression. Further details have been furnished lately by a report by M. Ad. Carnot to the Societe d'Encouragement. M. Clemandot's method consists in heating the metal so that it becomes sufficiently ductile and then submitting it during cooling to a strong pressure. He noticed that this treatment affected the structure of the metal in such a way that it acquired properties analogous to those brought out by tempering. The metal thus obtained differs considerably from steel simply cooled, by its finer grain, its greater hardness, and its greater resistance to rupture, particularly with certain grades of pretty high carbon steel. In these respects it approaches in quality steel tempered in water, without being identical with it. It has two different effects, almost simultaneously, an energetic and continuous compression, and a rapid cooling of the steel. The cooling is caused by the contact with the platform of the hydraulic press, and takes place much more rapidly than when the same piece is allowed to cool without being compressed. The remarkable results obtained by M. Clemandot are explained by the combined action of cooling and compression. The first, in its results, resembles the compression effected by hammering or rolling; the second, the effect of tempering by immersion. It has been urged that the piece of steel must be inclosed by a mold into which it fits exactly. It is, however, only necessary that the compression act upon two opposite faces. A square bar, whether straight, or curved to horse-shoe shape, need only be laid down flat and compressed between the two platforms of an hydraulic press. In order to obtain the best results, the cherry-hot piece of steel should be as rapidly as possible subjected to the pressure settled upon beforehand, ranging from 10 to 30 kilograms per square millimeter.

While the tempering process by immersion brings about an increase in the volume of the steel and a corresponding decrease in its density, the action of high mechanical pressure during the entire process of cooling tends to bring the metal back to its original volume or its normal density, thus preventing the creation of a state of intermolecular tension noted in tempered steel. Actual experiment has confirmed these theoretical deductions, so far as the resistance of the compressed steel to stress is concerned.

RAILWAY NOTES.

Improvements in the Permanent Way and Works of Italian Railways—By F. Biglia.—This paper contains the results of the second of the three commissions upon matters relating to the Italian railways. The Berne International Conference, recommended that the international gauge should be changed from 4 ft. 8.5 in. to 4 ft. 8.69 in. This was objected to by the French and Italian delegates, because in France many of the principal lines have a gauge of 4 feet 9.08 inches, and in Italy the gauge is fixed at 4 feet 8.89 inches, a mean between the French of 4 feet 9.08 inches, and the German of 4 feet 8.5 inches. The Italian Commission agreed to accept the gauge proposed at Berne as soon as it should be adopted by the French Government.

Foot Signals at Points.—The commission decided that these are not to be considered as stopping signals, their object being to enable the station-men to see from a distance how the points stand, and to show the engine-driver upon what line he is traveling. There was a long discussion as to the color to be adopted for these, a red ought to be used exclusively for stop signals, but nothing was decided. These signals are to be limited to the points at the ends of stations, and to those giving access to large groups of good sidings.

Level-crossing Barriers worked from a distance.—The following are the decisions of the Commission in regard to these. A bell is to be fixed near each barrier, and rung before it is moved, to give notice to travelers. Barriers must be visible from the points at which they are worked, which must not be at a greater distance than 1,600 feet. Lights are not to be provided, except in special places. One man is not to have more than two distant barriers under his charge, in addition to his own gate, and the levers must be within 32 feet of each other. The barriers are to be placed parallel to the line, at a distance of 6 feet 6 inches from the nearest rail; there is to be a separate lever for each side of the line, and the barriers are to be constructed so that they cannot be opened and shut by passers by. They are to be weighted so as to close gradually in the event of the connection with the lever breaking. The use of these barriers is to be confined to unimportant roads and to single lines of railway upon which the traffic receipts are less than 35,000 lire per kilometer per annum.

Three-throw Points—It was decided to allow these to be used, but not upon lines traversed by express trains; the central line must be straight. They may also be used on express lines at stations where all trains stop. A system of double points, by means of which trains running in either direction upon either of two lines of way, can either keep their own line or be shunted on to the other, is permitted to be used in certain cases, but limited to slow lines and sidings.

Attachment of Trolleys to Trains.—One of the questions discussed was whether trolleys might be attached to trains by slip-couplings. It was objected that the attachment being necessarily above the center of gravity of the trolley, there is a tendency to turn it in a vertical plane round the front axle whenever this encounters the slightest resistance. On the other hand the plan is most useful for drawing heavy loads up steep inclines, for when the workmen have to push the trolleys themselves, they arrive at the place where they are going to work exhausted, and, which is worse, in a state of heat which exposes them to attacks of fever in unhealthy

districts. The Commission decided to allow the attachment to slow trains on lines having gradients steeper than 1 in 100.

Traffic at Level Crossings.—On the Italian lines there is generally a level crossing at each station, and as these are situated in populous places, they are the occasion of constant complaints from the inhabitants, owing to the length of time during which the gates are closed, either on account of the trains being late or during shunting operations. There are also frequent crossings in the open country. If it is proposed to substitute a bridge for a crossing, the necessary approach is objected to, especially in level districts, when the necessary gradient would limit the load which animals can draw. Besides this, owing to the station-sidings it would often be necessary to carry the road across the line at some distance from the station, and this would necessitate a long diversion. The time during which the gates are closed can be limited by the use of signals, but, on the other hand, it is impossible to run quick trains when the driver has always to be ready to stop at these signals. After some discussion, the Commission decided (1st) that in order to insure sufficient protection of level crossings at which it is important to limit the time of closing the gates as much as possible, they might be entered in the time-tables and treated like stations, and provided with disk signals and electric instruments to give notice when the trains are late; (2d) that at less important crossings it will be sufficient to provide telegraph communication with the nearest station; (3d) that on main roads crossing lines of heavy traffic, especially where the roads have steam trams on them, it is essential that bridges over or under the railway should be built, and, considering the interests involved, the cost may be divided between the railway and the public bodies which would benefit by the change. It must not be forgotten that the cost of gate-keepers will be saved.

Ballast.—Ever since the construction of railways was commenced it has been a disputed point whether the ballast should cover the sleepers or be laid level with their upper surface; the former system protects the timber from the direct rays of the sun, from sudden changes of temperature, from moisture, dryness, and frost, and gives excellent results in preserving the sleepers from decay. These advantages are, however, denied by some engineers, who consider that covering the sleepers makes them decay more rapidly, and increases the first cost of the line and the difficulties of maintenance.

The Commission came to the conclusion that though uncovered sleepers may be preferable in northern climates, it is necessary in Italy to completely imbed them in the ballast.

Working strains allowed in Iron Roofs and Cranes.—The working strain allowed in bridges in Italy is 3.81 tons per square inch, provided that the breaking-strain is not less than 20.32 tons, and the limit of elasticity 9.52 tons per square inch. Italy being entirely dependent upon foreigners for supplies of iron, it is found more economical to use Belgian iron, which will stand these tests, rather than stronger but more expensive material. For roofs the Commission fixed upon working-strain, 5.08 tons; breaking-strain, 22.86 tons per square inch, with 8 per cent. extension. Various methods have been suggested for limiting the weights lifted by cranes, among others Hohenegger's apparatus, which indicates the weight which is being lifted, and automatically prevents the lifting of weight in excess of that which the crane is designed to carry. The Commission determined to conduct trials with this apparatus.

There is annexed to the Paper a report upon lighting carriages with oil lamps.—*Abstracts of the Institution of Civil Engineers.*

ORDNANCE AND NAVAL.

RE-ARMING THE NAVY.—About 400 of the new steel guns have been completed at the Royal Gun Factories, and these are nearly sufficient for the re-armament of the smaller ships of the Royal Navy. More than 150 of the new guns are of the 6-inch class of breechloaders, and seven-eighths of the whole are especially adapted for sea service. Large guns for the heavier ironclads are now in course of construction and all the guns now made being of the type described by Colonel Maitland in his recent lecture as the latest combination of all that is best in all the best systems, it is hoped that within a year or two the present deficiencies in the armament of the Royal Navy will be satisfactorily repaired.—*The Engineer.*

TORPEDO EXPERIMENTS IN BANTRY BAY.—Two experiments with fully charged Whitehead torpedoes have been made by two vessels of the Channel Squadron at Bantry Bay. The steam pinnace of the Minotaur discharged a Whitehead torpedo at a large rock at the head of the bay. The machine ran at a rate of 13 knots an hour, being loaded with a charge of 117 lbs. of gun-cotton. It was adjusted to run 400 yards, and was discharged when the pinnace was about 300 yards from the rock. The torpedo, a 16-inch one, weighed 600 lbs. It struck the face of the rock 7 feet from the surface and threw up about 30 tons of water to a height of 300 feet, also several pieces of rock. The result of the experiment was considered most satisfactory, the more so as the rock was very unfavorable for the purpose, containing a number of crevices and presenting no even surface such as a ship would. The base of the rock was nearly destroyed, large pieces being disconnected. The second experiment, conducted by the Neptune, was not successful; the machine did not go fair and missed. It ran its full course of 400 yards and sank. During the stay of the fleet numbers of successful experiments have been conducted with submarine mines and stationary torpedoes.

BOOK NOTICES.

PUBLICATIONS RECEIVED.

INTERNATIONAL Health Exhibition Library Catalogue. London: William Clowes & Sons.

Monthly Weather Review for August. Washington: Government Printing Office.

Papers of the Institution of Civil Engineers:

No. 1892.—The Ashti Tank. By Charles Toler Burke, M. Inst. C. E.

No. 1985.—On Galvanic Action Between the Various Irons and Steels in Sea Water. By Thomas Andrews, F. R. S. E.; Assoc. M.I.C.E.

No. 2014.—Water Supply in Peru and Distilling Apparatus at Iquique. By Charles Malcolm Johnson, R. N.; Assoc. M. I. C. E.

Abstracts of Papers in Foreign Transactions and Periodicals.

No. 2008.—The New Harbor of Trieste. By Friedrich Bornches.

No. 2015.—Old Water Supply of Seville. By George Higgin, M. I. C. E.

No. 2010—The Area of Sluice Opening for a Tidal Canal. By James Henry Apjohn, M. I. C. E.

No. 1972.—The Passage of Upland Water through a Tidal Estuary. By R. W. Peregrine Birch, M. I. C. E.

No. 1964.—A Dioptric System of Uniform Distribution of Light. By Alexander Pelhorn Trotter, Assoc. M. I. C. E.

No. 2000.—Wood Pavement in the Metropolis. By George Henry Stayton, Assoc. M.I.C.E.

London: Published by the Institution.

A Treatise on Steam-Boiler Incrustation. By Charles Thomas Davis. Washington: Industrial Publishing Co.

There is no doubt of the importance of the subject of this practical treatise. The author has endeavored to furnish "reliable information as to the various compounds and mechanical apparatus employed for the prevention of boiler incrustation," and has achieved a fair success. The book presents but little improvement upon former works on the same subject, Rowan's for example, so far as explaining the causes and cure of the evil are concerned, but is much fuller in its description aided by diagrams of different methods.

On the other hand, the author rests content with mere enumeration and brief description of the various processes. Of their relative efficiency the reader is left to draw his own inference.

A Treatise on Ore Deposits. By J. Arthur Phillips, F. R. S. London: Macmillan & Co.

That this treatise will be accepted as a standard authority may be safely assumed. The previous works of the author have earned for him the reputation of a careful and industrious contributor to the literature of metalliferous deposits. His "Manual of Metallurgy," and "The Mining and Metallurgy of Gold and Silver," are well-known books of reference in all libraries of general technical literature.

The first part of the new treatise is devoted to "ore deposits in general." This part may be read with profit by students of geology who have no interest in hunting ores. The various ways in which the accumulations of valuable metallic compounds have been brought about are discussed and fully illustrated by diagrams.

Beginning with superficial deposits, the author describes their accumulation under the mechanical action of water and the chemical reaction which has caused precipitation out of solutions.

The origin of Stratified Deposits is next considered, and the theories of precipitation with or without subsequent metamorphism, are clearly set forth. The dissemination through sedimentary beds receives its full share of attention.

The next section, Unstratified Deposits, would of itself make a valuable handy book for the mining engineer. It is devoted to the description of the so-called mineral "veins" of all kinds. In succession are presented Modes of Occurrence of True Veins, Intersections and Faults, Structure and Composition, Distribution of Ores in Lodes, Out-crop of Lodes, Grouping and Sequence of Minerals in Lodes, Influence of Depth, Influence of Country Rock, Age of Mineral Veins, Genesis of Mineral Veins, Theories respecting the Formation of Mineral Veins, Segregated Veins, Gash Veins, Impregnations, Contact Deposits, Fahlbands, Chambers or Pockets. Diagrams are abundant throughout.

Part Second describes the "Ore Deposits of the Principal Mining Regions," and is divided into shorter sections each of which deals with the mines of a country. In addition to the geological and physical features of the mining regions there is added in many cases the history of the earlier operations and the statistics of the later ones. It is not often that a book bearing a title suggesting only a technical value contains so much varied and in every way valuable information.

A Treatise on Chemistry. By H. E. Roscoe, F. R. S., and C. Schorleunner, F. R. S. Vol. III., Part II., 8vo, cloth, New York: D. Appleton & Co.

The second part of the volume on Organic Chemistry of the work which has been described as "the finest systematic treatise on modern chemistry," has just been published.

New discoveries are continually extending the confines of organic chemistry. A few years ago, all that was known concerning it could be summed up in a few brief paragraphs, but the magnificent discoveries in the department of dyes, the wonderful development of synthetical chemistry have led to increased activity in this branch of chemical science, so that to-day a description of its compounds requires a space equal to, if not greater than, that of mineral chemistry.

A full review of the contents of this book cannot be attempted here. A few remarks on this point, however, will not be out of place. Among the uric acid compounds, descriptions of caffcine and theobromine will be found. The similarity of their composition to that of certain of these bodies suggests that the preparation of these so-commonly used alkaloids from guano, may be possible.

Glycerot, generally called glycerine, is fully described. Its preparation, its properties, its derivatives (including nitro-glycerine), and its applications are thoroughly discussed. We find

that when "it is allowed to stand in a sufficiently concentrated condition at 0° C. (32° F.), crystals form after some days." Its boiling point is stated to be 290° C. (554° F.)* The carbo hydrates are treated quite fully, cane sugar naturally receiving most of the attention. Grape sugar is not neglected, but sorghum sugar receives scant justice and is dismissed with a paragraph. With cellulose, its explosive derivative gun-cotton, collodion also, and the details of paper-making come in for consideration.

For the benefit of those who desire more detailed information, foot notes containing references to original memoirs are given on nearly every page. Clear, beautiful illustrations, engraved especially for this work, are inserted where necessary.

In 1877, nearly eight years ago, the first of this series appeared, and the present volume, completing the work, fully sustains the promise of that initial portion.

The distinguished authors, Prof. H. E. Roscoe and Prof. C. Schorleunner, of Owens' College, Victoria University, Manchester, England, deserve our thanks and congratulations for having brought to a successful termination so beautiful and perfect a work on chemistry.

It is not excelled by any similar treatise in the English language.

The Attack and Defence of Coast Fortification. By Captain Edward Maguire, Corps of Engineers of the U. S. Army. Published by D. Van Nostrand, 23 Murray Street, New York City.

From the earliest times the problem of the defence of its coast has occupied the attention of every nation having a border on the sea. In every country the seaboard towns are the main sources of the nation's wealth. Consequently the defence of these towns from destruction or occupation by an enemy is a matter of interest to every inhabitant who has anything at stake, whether it be dollars or whether it be national pride. The whole history of the attack and defence of coasts is but a record of progress and development; progress in the art and science of war and development of the applied means of attack and defence. The close of the war of the rebellion found the United States the best fortified country in the world with the finest forts and the best guns. But the long and valuable experience of that war led to much scientific study of both ships and forts. The European nations have devoted much time and money to the problem of guns-afloat and guns-ashore. During the many years of costly experiments guns grew in size and power, and ships' armor increased in might and strength, and at the present time we have huge armored floating citadels like the Italian "Duilio." But ships must manœuvre and for that purpose they must possess certain very essential qualities—flotation, stability and sailing capacity. These qualities put a limit in the size of the ship and hence on the weight of its armor and armament. That limit has been reached, and to-day the problem of the attack and defence of coast-fortifications is susceptible of solution and the principles upon which that solution depends are simple in character and of application. The little book now before us aims at an exposition of these principles. It treats of naval fighting means, giving a description of the different kinds of war-ships, as well as discussing the operations of a fleet against coast-fortifications; it devotes much attention to coast-forts and batteries; obstructions and sea mines; accessory defences, the armament of batteries; the general measures of coast defence, and closes with an example of modern coast-defence. It contains many illustrations. The writings of the great European nations as well as of our own have been called upon by the author for material for his work. What originally commenced as a series of professional notes he has developed into a book. The introduction gives an insight into the author's object in publishing the work. It reads as follows:

"As a rule the periodical military literature, as well as the text-books, treat the above mentioned subjects only by piece-meal, and usually only with reference to secure particular work which the author at the time has on hand. Under such circumstances one is forced to wade through a great mass of material in order to garner that which is worth knowing. This is a tedious and often impracticable process. Books are expensive, professional libraries scarce; and a knowledge of French and German, at least, is almost indispensable to the student.

"Again: a great many of the text books go too much into the details of old forms, and devote too much attention to dead issues. The tendency is to force the young man to spend part of his life in a past age; that is, to encumber his mind with a mass of information which even his grandsire would have been glad to have forgotten."

There has of late years grown up the idea that torpedoes alone will constitute a sufficient defence for this country. Congressmen make long speeches in favor of torpedoes and refuse to vote an appropriation for forts and guns. Even some professional soldiers have been carried away with the defence of our harbors by means of submarine mines alone. The very uncanniness of the torpedo and the general ignorance of the masses of the true nature of submarine mines has invested them with a species of awe and admiration. The author of the book is an advocate of forts and big guns and closes his discussion of submarine mines as follows:

"Submarine mines can in no case replace guns, especially as their own security depends upon guns. Guns and passive obstructions may constitute an effective defence, but submarine mines alone—never. It must be distinctly borne in mind that a submarine mine has but one life, and, having been once exploded in action, it cannot be replaced; while the activity of the guns is limited only by the supply of ammunition.

"Submarine mines, more than any other weapon, call for experience, skill, training, and the closest attention on the part of those operating them. From the very nature of things they must be operated by "the few:" while guns can be fought by "the multitude," and without

* See p. 173, August, 1884, issue of this magazine.

very great training. It is a well-established principle that all engines-of-war should be as little complicated as possible, and as free as possible from delicate parts; therefore the main defence should never be left to submarine mines, which any one of a number of unforeseen accidents may render useless, and which can be operated by only a few men whom it would be difficult to replace in time of action."

While the book is written especially for the professional soldier it should not be without interest for every thinking citizen. There is very little of the purely technical in it, and as a whole it is easy of comprehension. The publishers have done their work well. The volume is a handsome one, clearly printed, and elegantly bound.—*Commercial Advertiser, Buffalo.*

A Practical Treatise on Electric Lighting. By J. E. H. Gordon, B. A., M. S. T. E., etc. New York: D. Appleton & Co. 1884. pp. 228. Price $4.50.

This book is from a pen which has already achieved a reputation by the production of an excellent treatise on "Electricity and Magnetism," doubtless known to many of our readers. In his first work, however, the author wrote from the standpoint of the physicist, while in the present work he writes rather from the standpoint of the inventor. This change of the author's position relatively to his theme is, as might be anticipated, detrimental to the book to a great extent.

It is undeniably to the credit, as much as we trust it may be to the profit, of the author to have sought to lend a hand in the practical development of the art of electric lighting. But in turning inventor he has placed himself in such a relation to this art that his judgment must inevitably suffer from the changed perspective. He is no longer sufficiently removed from the whole field to be able to see things as "outsiders" see them. What is immediately near him seems to grow in size, while everything else fades into insignificance. The partiality of the author to his own or his friends' methods would not be so objectionable were it separable from a certain indifference and prejudice which obscure or ignore the methods of others.

The book is divided into twenty-one chapters, but one of these (Chapter XIX.—"Central Station Lighting") is merely laid out, the five lines under this head being intended as a prospectus of a "long chapter" which is to be inserted there in a future edition, the author not being prepared, "for various reasons," to write it for the present edition. We venture to say that if there had been any central station on the "Gordon" plan to describe, one of these various reasons at least would have been removed. As for what has been done by Edison in central station lighting by incandescence, and by Brush and others in arc lighting, it was probably not worth mention.

Of the twenty filled chapters, about ten are extremely good, and the rest as extremely bad. The good chapters are those in which the principles underlying the art of electric lighting are analyzed and elucidated. In these chapters there is no evidence, at least, that the author has an axe of his own to grind. We think so well of these portions of the work that we regret that the author did not publish them separately with the excellent tables contained in the appendix, and, by so doing, give us a most excellent treatise on "The Principles of Electric-Light Engineering." Chapter I. (Principles of Artificial Lighting), Chapter II. (Conversion of Electric Currents into Heat), Chapter III. (Electrical Units, Heat, Work, etc.), and Chapter IV. (Rules for the Resistance of Divided Circuits) fulfill their respective missions in a very creditable manner, making intelligible much that has failed to become plain in the hands of other writers. We might say the same of Chapter IX. (Magnets and Electro-Magnetic Induction) and Chapter X. (General Principles of Electrical Generators), and also of Chapter XVII., though in this case the author has sacrificed much of the clearness for the sake of brevity. Chapter VIII. (Carbons for Arc Lamps) is one of the most interesting and valuable in the book, especially so since there is little said in other books on this subject. Chapter XI. (On Designing Dynamos, and on their Mechanical Construction) is that to which we feel disposed to award the palm for excellence. We believe that to many this chapter alone will be worth the price of the book, for it gives many practical hints and methods, and, above all, it teaches common sense. If we add to these Chapter XXI., which is merely a reprint of the "Rules for the Prevention of Fire Risks," drawn by the Society of Telegraph Engineers, and the Appendix, which contains a number of very useful tables, we shall have mentioned about all that can pass without adverse criticism. The chapters not yet named are those which are wholly or mainly descriptive, and they all suffer from the illusion of perspective which we have explained above. We fear that the unwary student will often get from these chapters impressions and prejudices that were better avoided. What concerns Mr. Gordon or his friends is very fully described, even to obsolete forms and to minute details. As for other inventors and inventions, they are either ignored altogether, or else passed over with descriptions too meager, too careless, we might say, to be reliable and useful.

In Chapter V. there is not even a mention of the Deprez-Carpentier current meters, after which were patterned those of Ayrton & Perry, which are so fully described. In Chapter VI. the lamp most extensively used the world over —the Edison lamp—receives the least attention, namely, one page with one illustration, which follow some ten pages, including fifteen plates and illustrations, devoted to the "evolution" of the Swan lamp. In Chapter VII. the author shows his deference for his friend, Mr. R. E. Crompton, by telling all he can about his lamp, and as little as possible about any others. Four forms of Crompton arc lamps are described at length, with numerous figures, and only two other lamps, the Serrin and the Brush, are referred to. Chapter XII. (Some Typical Alternating Current Machines) contains a "reference" to the machines of De Meritens and Siemens, a "criticism" of the Farranti machine, and a "description" of the Gordon dynamo.

Chapter XIII. (Some Typical Direct-Current Machines) begins with a full description of the Crompton-Burgin machine, after which come rather inadequate descriptions of the Brush-Siemens and "large" Edison machines. The author doubtless imagines he has given his readers "a representative selection," for he says in the preface: "In describing machines and lamps I have not thought it necessary to describe many, but have selected those which are typical of different classes." Chapter XIV. (Regulation of Machine) is evidently intended to force a conclusion, and this conclusion is printed in italics at the end of the chapter. Briefly, this conclusion is: *The true secret of successful regulation is Mr. Gordon's own plan.* Mr. Gordon's plan of regulation does not contemplate by compound winding, and of course he "doubts if compound winding, in spite of its apparent simplicity will be much used in the future, except for small machines!"

Mr. Gordon sees no earthly use in storage batteries, and Chapter XVI. is devoted to the proof of that doctrine. These details are sufficient to show that the descriptive portions of this book are to be taken with a rather large grain of allowance for the author's partiality and prejudices—a personal equation which undoubtedly would not appear if the author were not identified with the art as an inventor. As for the rest of the book, it is, as we have said already, most excellent, and it will perhaps bring the book into favor in spite of the faults we have just noted.

THE THEORY OF DEFLECTIONS AND OF LATITUDES AND DEPARTURES—WITH SPECIAL APPLICATION TO CURVILINEAR SURVEYS FOR ALIGNMENTS OF RAILWAY TRACKS. By ISAAC W. SMITH, C. E. 16 mo., morocco tucks. Price, $3.00.

Geometer is the Greek word for a land surveyor or measurer, and, at the present time, geometry would seem to be all Greek to a large portion of such geometers. Chiefly because of the false definitions of quantities given in the text books used in schools and colleges, on account of which graduates in mathematical courses, on attempting to reduce their theories to practice on any other than a paper field, are confronted with quantities of which they have had no previous knowledge, and are unable to solve the simplest problems beyond the compu. tation of the sides and angles of a triangle.

It is claimed by authorities in geometric science that their conclusions are based on definitions easily understood, and on self evident axioms and postulates, but any one of ordinary common sense, who will trust to his own judgment and not be overawed by the weight of authority, will find by examination that their premises are often in direct opposition to their conclusions.

An angle, for instance, is defined by Euclid (see Playfair's translation), as "the inclination between two straight lines which meet and are not in the same straight line;" by Legendre as "the quantity, whether greater or less, by which two straight lines which meet depart from each other as to their positions;" and by Davies as "the space, or the divergence, between two straight lines produced to intersection;" and from these widely different definitions, as a relation between two straight lines which *are not* in the same straight line, they each deduce the same elementary proposition, that the lines *are* in the same straight line when the angle is 180 degrees.

From these definitions it will therefore follow that the inclination, or the departure, or the space, or the divergence, between two lines is twice as great when they are portions of the same straight line as when they are perpendicular, or at an angle of 90 degrees.

This absurd conclusion, that the angle between two straight lines comes into existence only when they are produced to intersection, has been the source of countless blunders and much useless waste of money, especially on railway surveys, on which it is necessary to calculate the sign and magnitude of each tangential deflection on the alignment.

In proof of this might be cited a circular issued by the chief engineer of an important transcontinental road, instructing his assistant engineers to produce always to intersection tangent lines from the extremities of each circular arc; nor is this in any way a singular instance of super-mathematical stupidity. In a work for instance, on the elements of plane surveying and navigation, by the late Mr. Davies, professor of mathematics in the United States Military Academy of West Point, after defining an angle as the portion of a plane between two straight lines which meet at a common point, he gives four elaborate rules for determining the angle between two straight lines from their bearings and adds, in a note, that "the above principles are determined under the supposition that the two courses are both run from the same angular point, hence, if it is required to apply them to two courses run in the ordinary way, as we go around the field, the bearing of one of them must be reversed before the calculation is made."

In application of these rules it is then stated that, when the bearings of two courses are N 39 W and S 48 W, the angle between them is 93 degrees when measured from the same angular point, and 87 degrees as "we go around the field." The same confusion of ideas exists as to the natures of other trigonometric quantities.

A ship sails 100 miles in a direction 30 degrees right or left of a north direction; the departure at right angles to a north line, is a half mile to the mile, and has the same sine with the bearing, and this rate of departure, equal to five tenths, is the sine of the bearing, and the departure in 100 miles is 100 times the sine of 30 degrees and equal to 50 miles.

But turning to Legendre it will be found that the sine is the perpendicular let-fall from one extremity of an arc upon a radius through the other extremity, and hence it would follow that a sine is not a constant quantity, but varies with the radius of the arc by means of which it is measured.

Plane trigonometry, or the problem most frequently recurring in plane trigonometry, is the determination of the relative positions of points, or the direction and distance from one point to another, and it is singular that direction is seldom or never considered or even alluded to in text books.

A direction may be defined either as from one known point to another, or by the bearing or deflection, right or left, from some known direction. The relative position of two points may also be defined by the difference of their co-ordinate distances from two axes of known directions or, when the axes are rectangular, by the differences of their latitudes and departures.

The deflection from any direction to the same direction again is equal to 360 degrees; if the deflection from a direction BA to a direction B C is 180 degrees, A, B and C are on the same straight lines; the total deflection from one direction to another is the algebraic sum of the partial turns made in making the deflection; the departure of a line is the perpendicular distance, right or left, to the terminal point from an axis of given direction through its initial point; the sine of the bearing from the given axis is the rate of departure, and the sign of the sine and departure is the same with that of the bearing; the departure of the closing line from the initial to the closing point of a series of lines is the algebraic sum of the departures of the several lines composing the series. This is a brief summary of the principles of plane trigonometry, and the quantities are the same by the rough calculation of which the hunter or explorer can approximately determine the direction and length of the closing line from his starting point.

The theory of latitudes and departures has been long in use in plane surveying and navigation, but the theory of deflections, although applied to some extent on railway surveys, has not been reduced to a mathematical system. The object of the work is the application of these theories to the solution of problems in curvilinear surveys for alignments of railroad tracks, and it contains, besides the strictly mathematical propositions, the solution of all classes of problems generally presented in such works, and of many which, although of constant application, have hitherto been solved by the process known among surveyors as fudging.

Many of the propositions are not new, but they are derived by an original process, and based on the true nature of trigonometric quantities, and are an extensive experience in all classes of surveys in the Eastern States; in Mexico, and on the Western Coast, in the service of the Northern, Southern, Central, and Oregon Pacific railroads, in yard work and in the several capacities of leveler, transitman, assistant, Division and Chief Engineer, and on reconnoissances, preliminary and location surveys, as well as on construction.

Surveying does not require a high order of engineering talent, but what must be done should be well done, and few can realize the great and useless expenditures by men who can compute without understanding the quantities computed, or who understand their quantities without the ability to compute.

MISCELLANEOUS.

M. Jacquelain has endeavored to procure a pure carbon for electric purposes that should be as hard and as conductive as gas carbon. He first takes gas carbon, which he submits to four processes: (1) Treatment with dry chlorine at a red heat for thirty hours; (2) treatment with hot alkali for about three hours; (3) immersion in hydrofluoric acid—one to two of water—at a temperature of 15 deg. to 25 deg.; (4) carbonized by heating strongly in the vapor of a high boiling hydrocarbon, for commercial purposes gas tar will do well. All these operations may be performed after the carbon has been cut into sticks. By these processes, which do not seem to be new in any particular, the *Scientific American* says, the impurities have been reduced to a minimum, and a good, pure carbon is obtained.

On the Preservation and Use of Beechwood for Railway Sleepers.—By Claus.—The use of railway sleepers of beechwood has hitherto been very limited. In Germany only about 1 per cent. of the sleepers is of this wood, and in Austria 3 per cent., although large beech forests are available in both countries. The slight durability of ordinary beech sleepers is the chief reason of this; their life is reckoned at two and a half to three years, while oak will last fourteen to sixteen, and fir seven to eight years. The best method of preserving beech sleepers appears to be impregnation with creosote. Prepared in this way the average durability of the wood for railway purposes appears to be about eighteen years, while chloride of zinc only preserves it for fifteen years. Sleepers impregnated with sulphate of copper or sulphate of barium had to be replaced after four or five years. In many places the expense of impregnated beech-wood is so much less than that of oak, that it might be used with great advantage were it not for the peculiar manner in which some beech sleepers have been observed to give way under sudden strain. In such cases the exterior of the wood appears perfectly sound, while the heart has become rotten and affords no hold for spikes or bolts.

In France the proportion of beech sleepers is much larger than in Germany; they are chiefly impregnated by Blyth's method, by which each sleeper absorbs about 22 lbs. oil of tar, while in Germany 36 lbs. of creosote are injected. The French method does not appear to remove the organic matters, which are liable to decomposition.

In Germany Rutger's method is in use for preparing these sleepers. They are gradually raised to a temperature of 130° Centigrade, and dried for at least four hours, until they cease to give off vapor and are completely warmed throughout. They are then removed, on the same trucks upon which they have been dried, to the creosoting apparatus. This consists of a horizontal cylinder with hermetically closed doors in which a partial vacuum is produced and maintained for half an hour. The warm creosote is then allowed to enter the cylinder, and the whole is subjected to a pressure of 100 lbs. per square inch for one hour. Before injecting the creosote it is advisable to extract by boiling so much of the sap from the timber as is possible. This should be done while the wood is new and before the sap has begun to ferment. After this operation the sleepers must be allowed to dry for two or three months. Beechwood prepared in the above manner appears to be well suited for railway sleepers.—*Dingler's Journal.*

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THEORY OF THE SLIDING FRICTION OF ROTATION.

By ROBERT H. THURSTON, HOBOKEN, N. J.

From Transactions of the American Society of Mechanical Engineers.

Sliding friction in systems of mechanism gives rise to losses of energy and to increase of resistance which are usually very considerable, and which are often the only sources of "lost work," and of the reduction of efficiency below its maximum value—unity. In any well-proportioned and properly managed machine or train of mechanism, the wastes of energy are due solely to friction; in badly-proportioned mechanism, subject to overstrain or shock, causing deformation of parts, energy is lost equal in amount to the work expended in producing permanent distortion. But as the engineer generally only considers cases of correct construction in determining the magnitude of such waste, it may be asserted, as a general and fundamental principle, that, in all good engineering, the sole cause of waste of mechanical energy is friction. These facts and this principle sufficiently indicate the importance to the engineer of a careful study of the magnitude and of the method of such losses.

The writer has elsewhere* given the results of experimental determinations of the values of the coefficients of sliding friction, and has shown that the lost work in mechanism varies very greatly in amount; that it is, under favorable circumstances, vastly less than has been generally supposed; and that it is influenced, where lubrication is employed, by every change of velocity of rubbing, of temperature, and of intensity of pressure, as well as by the character of the lubricant.

In machinery and mill-work, and in mechanism generally, it is usually found that the wastes of energy caused by sliding friction are principally due to friction of rotation; *i. e.*, to the friction of shafting, of journals, and of pivots in their bearings. This form of friction, and this method of waste, are the subjects of the paper here presented. The friction of straight sliding pieces has been frequently studied and is well understood; that of rotation has been less fully investigated, although considered at some length in a few treatises. The importance of the subject is such, however, as will justify the most extended examination.

The Friction of Journals causes a waste of the energy traversing a machine, which is dependent in amount upon the velocity of rubbing, the magnitude of the load, the method of distribution of the resulting pressure, and of variation of its intensity, the size of the journal, the nature of the lubricant and its physical condition, especially as determined by its

* *Friction and Lubrication*, Railroad Gazette Publishing Company, New York, 1878 *Materials of Engineering*, Part I., 2d Edition, J. Wiley & Sons, New York, 1884.

temperature, and on the value of the coefficient of friction as determined by all these modifying conditions.

A journal in good order, well-fitted, and smoothed down by prolonged working, should never show evidences of measurable wear. Such journals have sometimes been known, by the writer, to show no appreciable alteration of form and fit after years of constant work.

The First Case of permanent fit of journal is that in which the journal is exactly fitted to its bearing when new, and so perfectly adjusted that no sensible wear takes place. In this case, the pressure brought upon the rubbing surface by the load is distributed by a certain method of yielding of the loaded metal, and according to a simple and definite law, the investigation of which is one of the principal objects of this paper. Under this law, an adjustment takes place which, if the bearing surfaces are sufficiently large, of good material, and well lubricated, is permanent.

The Second Case is that in which wear occurs, and until all parts of the journal and bearing in contact wear until a "fit" is thus attained, such that every part is compelled to carry equal pressure, and until wear ceases to be observable.

The Third Case to be considered is that in which the journal is loose and the bearing surface, or surface of actual contact, is assumed to be a straight band of inconsiderable width.

These are the three typical cases for cylindrical journals, and these cases only are to be here studied. Actually, in practice, probably, neither case is often met with; the real condition of the journal is usually intermediate between one or the other pair of these type-examples.

It is evident, from what has been just stated, that the friction of journals, other things being equal, depends greatly for its amount upon the method of distribution of pressure, and is not necessarily, and probably may not be often, measured exactly by the product of the load on the journal by the coefficient of friction. It may be sometimes, and in fact often is, very much greater. It thus becomes an important problem to determine the manner in which variation of intensity of pressure affects the total resistance due to friction, and the method of that variation as produced by the different modes of fitting journals.

THE WORK DONE AND HEAT DEVELOPED, by the friction of any journal, is measured by the product of the total normal pressure on its rubbing surfaces into the mean coefficient of friction, and into the space traversed by the surface of the journal, relatively to the surface of the bearing, in the given time.

If p represent the mean intensity of pressure, l the length of journal, θ the angle over which the pressure distributed, r_1 the radius of the journal, f the mean coefficient of friction,* and n the number of revolutions made in the given time, the work of friction will evidently be

$$U = p.l.r_1\ \theta.\ f.\ 2\,\pi\, r_1\, n$$
$$= 2\,\pi\, r_1^2\, f\, p\, l\, n\, \theta \quad \ldots \quad (1)$$

When $\theta = \pi$, as in a journal receiving no pressure from its cap,

$$U = 2\,\pi^2\, r_1^2\, f\, p\, l\, n\,;$$

and when $\theta = 2\,\pi$, as when the cap is screwed down hard,

$$U = 4\,\pi^2\, r_1^2\, f\, p\, l\, n.$$

When the load is fixed, the intensity of pressure varies inversely as the area of the journal, and $p\, l\, r_1\, \theta$, becomes constant. Hence in such cases, the resistance of friction, $f\, p\, l\, r_1 \theta$, is constant, and the work of friction and energy wasted becomes proportional to the diameter of the journal; while both quantities are independent of the length, except so far as it affects the coefficient of friction. Journals are therefore properly proportioned by making their diameter such as is dictated by considerations of strength and safety against "springing," and determining their length by reference to the loss of work by friction and the liability to heating.

The minimum limit, as to length, is set by this last consideration. As has been fully shown by the writer, the coefficient of friction increases with increase of bearing area and consequent decrease in intensity of pressure; the conclusion therefore follows that bearings should be as short as is consistent with security against heating. This conclusion is the more

* With good lubrication, it may be assumed that, in heavy machinery and under pressures not far from 100 pounds per square inch (7 kgs. per sq. cm.), the value of f may be reduced below one per cent., varying approximately inversely as the square root of the intensity of pressure.

important from the fact that a long journal is liable to spring, and thus to concentrate pressure at the end, and to cause heating in that way. With every diameter of shaft, therefore, there is a limit beyond which no increase of length of journal will prevent heating. With a given shaft, heating under a given load, no increase of diameter will reduce liability to heat—if the shaft does not spring—and increasing its length may afford advantage only up to a limit.

THE HEAT DUE TO FRICTION, H, is proportional to the work done on the journal, and is measured in thermal units by the quotient of that work U, by the mechanical equivalent of heat J, *i. e.*,

$$H = \frac{U}{J} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

This heat is carried away by conduction to adjacent masses, and by radiation. If it is carried away as rapidly as it is produced, the journal remains cool; if not thus carried off, the journal heats up until the rate of dispersion is equal to that of production, or until it becomes necessary either to apply cooling agents or to stop the machine.

THE TEMPERATURE ATTAINED by a journal when thus heating is limited by the facilities for conduction and radiation of heat from it. The maximum *safe* temperature is that beyond which liability to rapid and dangerous heating is incurred, and is always below the temperature of decomposition or vaporization of the lubricant. A warm journal will often work better than a cold one; a hot bearing is always a source of danger. A journal so proportioned as to run warm with good lubrication is to be watched with the utmost care. As already seen, since the tendency to heat increases directly as the intensity of pressure, and as the amount of work done, and inversely as the area across which the heat can be transmitted, the diameter of the journal, if it be sufficiently strong and stiff, does not affect this phenomenon.

CASE 1.—THE PERFECTLY FITTED JOURNAL is the most interesting of the three cases here to be considered. When a journal is exactly fitted to its bearing,* as is usually the fact, without pressure, the action of the load will cause a minute change of form, which, although quite imperceptible, will produce a variation of intensity of pressure between the rubbing surfaces, from a maximum on the portion normal to the line of direction of the resultant load, to zero on the surfaces parallel to that line, and according to a simple and easily determined law.

This Method of Distribution of Pressure, which was, as he believes, originally investigated by the writer, is determined in the following manner:

The maximum intensity of pressure under which any journal of good form and correct proportions may be worked, is from 500 pounds to the square inch, with iron journals, to about 1,000 pounds with steel (35 to 70 kgs. per sq. cm.); the elastic limit of the bearing metal is always far above these figures, and that of the metal of the journal usually very much higher still. The compression of the metal, under working pressure, will be proportional to the intensity of the pressure at each point, and this principle will determine the law of distribution of pressure. The intensity of the pressure will be everywhere proportional to the elastic displacement of the metal.

Let p represent the intensity of pressure on any element of the surface of the journal having a length l, and a breadth $r_1\, d\theta$, and let N represent the normal pressure on this elementary area $l\, r_1\, d\theta$; then

$$N = p\, l\, r_1\, d\theta \quad . \quad . \quad . \quad (3)$$

The sum of all the vertical components of these elementary normal pressures, $p = N \cos.\ \theta$, where θ is measured from the vertical, is equal to the load W on the journal; *i. e.*,

$$W = \int p\, l\, r_1 \cos.\ \theta\, d\theta. \quad . \quad (4)$$

But the normal pressure p varies from a maximum, at the bottom of the bearing, to a minimum at the sides, there becoming zero when the bearing is a semi-cylinder. At intermediate points the normal pressure is

$$p = p_1 \cos.\ \theta,$$

in which quantity p_1 is a constant, the value of which is to be determined. The value of p being obtained, and introduced into the formula,

* The custom now common of grinding journals to size, and sometimes of scraping the bearing, makes this an increasingly frequent case.

$$W = p_1 \, l \, r_1 \int \cos.^2 \theta \, d\theta. \quad . \quad (5)$$

which is to be integrated between the limits

$$\theta = + \frac{\pi}{2}, \; \theta = - \frac{\pi}{2},$$

to obtain W in terms of p_1; when the journal bears upon a semi-cylindrical surface, or between the positive and negative values of θ for any other method of bearing. From the relation thus obtained the value of p_1 is deduced. It will be seen that p_1 is the measure of the maximum intensity of pressure between the rubbing surfaces, occuring when $\theta = 0$, *i. e.*, at the bottom line of the bearing.

To Determine the Maximum Pressure p' on the journal, let A C B, Fig. 1, represent the trace of the bearing surface upon the vertical plane, the journal being perfectly fitted and unloaded. When the load comes upon it the journal will sink a minute distance, O O′, C C′, A A′, B B′, and will rest in equilibrium between the elastic resistance to compression, thus brought into play in the metal, and the weight sustained by the bearing, the surfaces of contact taking the new position A′ C′ B′, of which every point now lies directly under its original position, and at a distance from it equal, at every point, to O O′. The compression of the metal in the direction of the normal pressure p, will be at each point, as E, equal to E I. The product of this vertical displacement, E J, into cos. θ; and the intensity of the pressure, the elastic limit of the metal

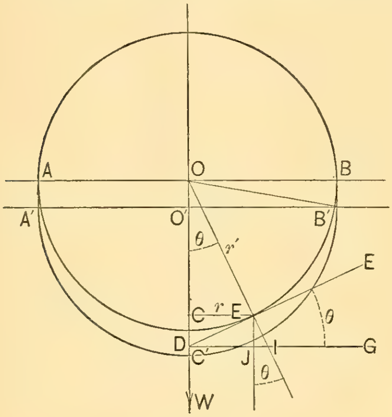


Fig. 1.

not being exceeded, will be proportional to this compression, varying from 0 at B′ to a maximum p' at C′. At any intermediate point, the compression is, for a small total depression of the shaft $\overline{\mathrm{O\,O'}}$ cos. θ, and the intensity of the pressure, consequently, p' cos. θ.

Since the load, W, is sustained by the sum of the vertical component of these normal pressures, each of which is of the intensity,

$$w = p \cos. \theta = p_1 \cos.^2 \theta,$$

$$W = \Sigma w = p_1 \, l \, r_1 \int_{-\theta'}^{+\theta'} \cos.^2 \theta \, d\theta,$$

$$= p_1 \, l \, r_1 \left(\tfrac{1}{2} \theta' + \tfrac{1}{4} \sin. 2 \theta \right)_{-\theta'}^{+\theta'}$$

as before, and

$$p_1 = \frac{W}{l r_1} \div \left(\tfrac{1}{2} \theta + \tfrac{1}{4} \sin 2 \theta \right)_{-\theta'}^{+\theta'} \quad . \quad . \quad (6)$$

When $\theta' = \frac{\pi}{2}$,

$$p_1 = \frac{W}{1.57 \, l \, r_1} = \frac{0.64 \, W}{l r_1};$$

and the pressure at any point, E, of the journal, has the intensity,

$$p = p_1 \cos. \theta = \frac{0.64 \, W \cos. \theta}{l \, r_1} \quad . \quad . \quad (7)$$

When $\theta' = \frac{\pi}{3}$,

$$p_2 = \frac{W}{1.48 \, l \, r_1}; \; p = \tfrac{2}{3} \, \frac{W \cos. \theta}{l \, r_1}, \text{ nearly}; \quad (8)$$

and the maximum pressure is nearly equal to four-thirds the load on the journal divided by its projected area on the horizontal plane, and is very nearly the same as in the previous case, although one-third the bearing surface has been removed. This is often done by engineers in charge of heavy machinery, to prevent risk of "gripping" or "binding," should the bearing heat.

It is evident that the same method applies to the case of the spherical journal.

The Extent of Compression is determined by the magnitude of the modulus of elasticity of the metal compressed, thus, for a pressure of 1,000 pounds per square inch (70 kgs. per square cm.) on a bronze bearing, the maximum compression would be but $\frac{1}{12000}$ the thickness of the "brass."

The Force of Friction, at any element, E, is, for the full journal,

$$fp = \frac{0.64\ W \cos.\theta}{l\, r_1}, \quad . \quad . \quad . \quad . \quad (9)$$

and varies from zero at $\theta = 90°$ to a maximum, at $\theta = 0$, when

$$fp_1 = \frac{0.64\, W}{l\, r_1}.$$

The Total Pressure on the bearing is

$$P' = 0.64\ W \int_{\theta=-\frac{\pi}{2}}^{\theta=+\frac{\pi}{2}} \cos.\theta\, d\theta$$

$$= 0.64\ W \left(2 \sin.\frac{\pi}{2}\right)$$

$$= 1.27\ W \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

The Total Force of Friction is

$$f P' = 1.27\, f\, W \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

The Moment of Friction is

$$M = f P' r_1 = 1.27\, f\, W\, r_1 \quad . \quad . \quad (12)$$

The Work of Friction is

$$U = M\, a = 1.27\, f\, W\, a\, t\, r_1$$

$$= 2.5\, f\, n\, r_1\, t\, \pi\, W, \quad . \quad . \quad . \quad (13)$$

where a is the angular velocity of the shaft, t the time taken, and n the revolutions made in the unit of time.

The Power lost in Friction is

$$U \div 550\, t = 2.5\, f\, n\, r_1\, \pi\, W \div 550, \quad (14)$$

when the units are British and the time is measured in seconds.

As will be seen later, the resistance, the work done, and the power wasted, are 1.3 times as great as in a journal loosely fitted, in which the rubbing surfaces are in contact only along a narrow band parallel to the axis of the journal. The case above considered assumes a fit originally and no subsequent wear. In such case, the journal must be of such size that the maximum pressure, p_1, may be below that at which the unguent is liable to be forced out, or heating to occur.

CASE 2.—UNIFORM PRESSURE ON THE RUBBING SURFACES may be observed in cases of journals so small as to wear slowly under their loads, or, perhaps, when heating, as is often the case, causes the "brass" to grasp the journal by springing the sides inward. Both are familiar cases to every mechanical engineer who has had much experience, especially if accustomed to the management of steam machinery.

In well-designed machinery, a bearing is usually composed of a softer metal than the journal which it supports; it therefore takes the wear, and if the extent of rubbing surface is small the journal is merely "smoothed up," while the bearing wears down. If the surface is too small, the bearing may be abraded and "cut," and both it and the journal rapidly injured. If, however, the surface under pressure does not cut, wear takes place slowly, and without excessive waste by friction. Every bearing surface, if not abraded, will, whether fitted or not, wear under heavy pressure, but with decreasing rapidity, until all parts sustain a certain intensity of pressure, when the rate of wear becomes a minimum, under a pressure which is a minimum for that bearing under the existing conditions as to lubrication. In some cases, the whole bearing surface may not be brought into play, the uniform pressure, so established by wear over a part of it, being sufficient to carry the load without further wear. These two cases are probably the most usual in all cases of heavily loaded, or carelessly fitted, journals, as the preceding case represents the usual case of well-fitted, lightly, or fairly loaded bearings. in every case, there is a certain pressure-limit, above which wearing will take place and below which it becomes inappreciable; the bearing will therefore wear down until the pressure due the load is so distributed that this pressure-limit is everywhere reached over a certain limited area, and wear ceases, or until all parts of the bearing are brought to a state of minimum wear under a uniformly distributed pressure.

In the case here studied, the pressure is of uniform intensity, p_1; that on any elementary strip of bearing, of length l and breadth $r_1\, d\theta$, is $p_1\, l\, r_1\, d\theta$; its vertical component is $p_1\, l\, r_1 \cos.\theta\, d\theta$, and the total load is, for a semi-cylindrical journal,

$$W = p_1\, l\, r_1 \int_{\theta=-\frac{\pi}{2}}^{\theta=+\frac{\pi}{2}} \cos.\theta\, d\theta$$

$$= 2\, p_1\, l\, r_1; \quad . \quad . \quad . \quad . \quad (15)$$

and the intensity of the uniform pressure attained is

$$p_1 = \frac{W}{2 l r_1} \quad . \quad . \quad . \quad . \quad (16)$$

The Total Pressure on the journal surface is

$$P' = p_1 \, l \pi r_1$$
$$= \tfrac{1}{2} \pi W = 1.57 \, W \quad . \quad . \quad . \quad (17)$$

or 0.57 greater than the load.

The Total Force of Friction is

$$f P = 1.57 \, f W \quad . \quad . \quad . \quad . \quad (18)$$

The Moment of Friction is

$$M = f \, P' \, r_1 = 1.57 \, f \, r_1 \, W \quad . \quad (19)$$

The Work of Friction is

$$U = M \, a = 1.57 \, a \, f \, t \, r_1 \, W$$
$$= \pi_2 \, f \, n \, t \, r_1 \, W,$$
$$= 10 \, f \, n \, t \, r_1 \, W, \text{ nearly.} \quad (20)$$

or 1.57 that on a flat surface, or on a loosely fitting journal.

Were the angle of contact reduced, making the angle $\theta' = 30°$, the friction becomes but 5 per cent. greater than that of an equally loaded flat surface, or of a loose journal. It is thus seen that, where ample area of bearing surface can be secured, it is best given the form of a strip or band lying along the bottom of a long "brass," rather than made to cover the full semi-circumference of a shorter journal.

Case 3.—A Loosely Fitting Journal, A B C, before wear has produced a sensible widening of the line along which contact originally takes place between journal and bearing, when in operation, carries its load at a line parallel to the axis of the journal, and at one side of the line of vertical resultant pressure (Fig. 2). If at the lowest point, B, at the starting, it rolls up the side of the bearing until,

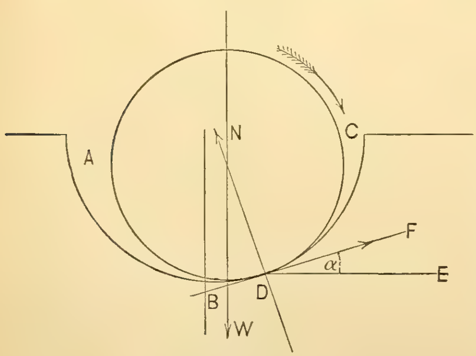


Fig. 2.

at some point, D, the inclination becomes equal to the angle of friction B N D, E D F, when it ceases its upward movement and continually rotates, sliding on the line whose trace is D, as long as the coefficient of friction remains constant, or rising with increasing, and falling with decreasing, friction, continually finding new positions of equilibrium until motion ceases, or the conditions again become constant.

At any one instant, there are three forces in equilibrium, the weight W, on the journal, the normal reaction, N, of the bearing, and the resisting force of friction, $F = f N$, which may be represented by the sides of the triangle N B D. Then, since N and F are at right angles

$$W^2 = N^2 + F^2$$
$$= (1 + f^2) \, N^2 \quad . \quad . \quad . \quad . \quad (21)$$

The Normal Pressure is

$$N = \frac{W}{\sqrt{1+f^2}} \quad . \quad . \quad . \quad . \quad . \quad (22)$$

The Force of Friction is, since $a = \varphi$, the angle of friction,

$$F = \frac{f W}{\sqrt{1+f^2}} = \frac{W \tan. \varphi,}{\sqrt{1+\tan.^2 \varphi}} = W \sin. \varphi \quad (23)$$
$$= f W \text{ nearly.}$$

The Moment of Friction is

$$M = F \, r_1$$
$$= W \, r_1 \sin. \varphi$$
$$= \frac{f W r_1}{\sqrt{2+f^2}} \quad . \quad . \quad . \quad . \quad . \quad (24)$$

The Work of Friction, or energy wasted, is

$$U = W \, a \, t \, r_1 \sin. \varphi = \frac{f W \, a \, t \, r_1}{\sqrt{1+f^2}}$$
$$= 2 \, W \pi \, n \, t \, r_1 \sin. \varphi = \frac{2 \, W f n t r_1}{\sqrt{1+f^2}}. \quad (25)$$

This case is thus seen to be that producing least waste of work and energy, and hence, in that respect, most desirable; but it is evidently a purely ideal case which can never be obtained in practice. If approached too closely, rapid wear, heating, and all the consequent cost and damages are increased. Case 3d is that of minimum friction, but of maximum wear and heating, as Case 1st that of minimum wear, and Case 2d that of maximum friction. In practice, the best ar-

rangement is usually, so far as the writer can judge from his own experience, that of freeing the sides of the bearing by cutting them away so as to clear the journal entirely to an angle of at least 30° from the horizontal, and even 60° for very long, stiff journals, moderately loaded. This gives a modification of either Case I. or Case II., and, on the whole, minimum friction and wear.

In conclusion, it may be considered proven that:

(1.) A perfectly-fitted cylindrical or spherical bearing of ample area of rubbing surface, will, in the absence of wear, have the pressure distributed in such manner as to make it zero at the sides, and a maximum at the bottom of the bearing, varying at intermediate points as the cosine of the angle included between the given point and the bottom of the journal.

(2.) The friction on such a cylindrical journal, and the lost work, exceed by above one-fourth that of the ideal case of bearing on a line, or that of flat surfaces under the same load.

(3.) A bearing so proportioned as to wear constantly, but without "cutting," will be subjected to uniform pressure throughout the area of rubbing contact.

(4.) The friction on such a bearing is nearly 60 per cent. in excess over that of the ideal case, or on a flat surface similarly loaded; it should always be relieved by freeing the sides from pressure in the manner often practiced by engineers, as above described.

(5.) Any journal, wearing smoothly and symmetrically, and without shake, will in time wear to a fit, such that the pressure upon its surface will be of uniform intensity throughout the whole area brought into bearing, and the rate of wear reduced to a minimum, while the waste by friction becomes a maximum.

(6.) Maximum efficiency of machinery in which journal friction is the main source of waste of work and energy, is secured by giving the journals such diameter that they will neither twist nor spring under their loads, such length that the load may be carried principally on the lower portion of the bearing, and such form that the "brass" shall not bind or grasp the journal, or in any way subject the journal to serious lateral pressures. All lateral pressure due to grasping or binding action decreases efficiency.

The proper size of journal is, as is evident from what has preceded, determined only in part by the consideration of the amount of power and energy lost by its friction. Since to increase or diminish the diameter of a journal increases the speed of rubbing in precisely the same proportion in which it diminishes the intensity of pressure produced by any given load it is evident that the work wasted and the heat produced on the unit of area of bearing surface is approximately the same, whatever the diameter of journal, within moderate limits; for, within such limits the coefficient of friction may be considered as constant. The *diameter* of journal is, therefore, determined by the strength and stiffness demanded, and not by the liability to heat, and is calculated by the rules for strength of materials.

The *length* of a journal is determined by reference to the laws of friction. A convenient method is to fix, by reference to experiment, a quantity of work of friction which may be safely allowed for the proposed journal, reckoned per unit of its area. Thus, the writer has found for the crank pins of marine engines, under intermittent pressure, $60,000f$, measured in foot-pounds, to be a good allowance; Rankine found $44,800f$ to be a good figure for locomotive practice; $50,000f$ is an intermediate figure sometimes taken for general practice. For unintermitted pressure, still smaller values must be taken.

Then the work of friction is nearly per unit of area,

$$\frac{f\,P\,V}{l\,d} = 60,000\,f, \quad . \quad . \quad . \quad (26)$$

and

$$\frac{P}{l\,d} = p = \frac{60,000}{V} \quad . \quad . \quad . \quad (27)$$

Thus the intensity of pressure is limited by the velocity of rubbing, and the given load, P, on the proposed journal being divided by this pressure, p, the length must be at least

$$l = \frac{P}{p\,d} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (28)$$

in which expression d is known already by calculations of strength.

ON WATER SUPPLY.

Papers read before the Conference of the Society of Arts on the Water Supply held at the International Health Exhibition in July.

From the "Journal of the Society of Arts."

II.

Sources of Water-Supply.

BY JAMES MANSARGH,

M. Inst. C. E., and M. E., F. G. S., F. M. S.

It used to be a popular belief that if a well were sunk at any place to a sufficient depth into the ground, there would be reached an inexhaustible reservoir of water, a store that had been filled in some mysterious manner at the creation of the world, and would suffice for the use of man for all time.

It is now well known that all supplies of water, whether found upon the surface or below it, in underground depths, are derived from the rain which falls upon the earth, and that it depends upon the geological character of the surface receiving the rain whether it shall run off in the form of streams and rivers, or soak in and be apparently lost.

Rain is produced from the evaporation of invisible aqueous vapor, principally from the ocean, by means of solar heat, its condensation, primarily into the shape of clouds, and subsequently into the form of drops, which fall to the ground.

The sea is thus a storage reservoir of boundless capacity, and the sun is the great prime mover which pumps the water up from this reservoir, distributes it over the land, and lifts it to the hills, where it may be impounded in natural or artificial lakes, and thence delivered by gravitation to the claims below.

After being discharged on the earth in the shape of rain or snow, a part of the water is re-evaporated, but the greater part begins at once to travel downwards, either over the surface, in the form of rills and streams, and so on to the ocean, whence it came, or through the surface, if this is permeable, into fissured or porous rocks below.

A portion of this latter water passing into the ground at high levels, has several courses open to it. It may appear in the shape of springs at lower levels, or rise in the beds of rivers, or run out through fissures on to the sea beach, or sink below sea level, whence it will be recoverable only by artificial means.

Nature has in this way provided water from one great source in ample quantity for the use of man, but works of varying character, under differing local circumstances, must be constructed to store and utilize it.

Altitude and the geological structure of a district are the two principal factors which determine what the source of water supply must be in such a district. The two great classes into which sources may be divided are (*a*) above-ground and (*b*) under-ground sources.

The former (*a*) has several subdivisions, which may be described as follows:

1. Water may be taken from the heads of streams by laying pipes right up to the springs, to convey it away for supply without any intermediate storage, as in the case of Lancaster. This is a source which in some sense belongs to the two classes, for the water is taken just as it ceases to be underground water, and is being delivered on to the surface above ground.

2. It may be obtained from a natural lake like Loch Katrine, as in the case of Glasgow.

3. It may be collected from a high-lying watershed area, by impounding a number of small streams in artificially constructed reservoirs, as is done for the supply of Manchester.

4. It may be taken from a large river flowing past the town, and is done in the case of the Thames and Lea for the supply of London.

The second class (*b*) is not divisible in the same way as (*a*), but may be taken as embracing supplies of water obtained from many varieties of geological stratification, such as chalk, oolites, coal measures, millstone grit, magnesian limestone, Bagshot sands, and many others.

All water, when discharged upon the

earth as snow or rain, is practically pure, but its character is very soon changed by the material it comes in contact with on the surface, or in passing through underground fissures and channels. Take, for example, the rain which falls upon the chalk downs of Sussex, or any other similar geological area. It sinks at once beneath the smooth and rounded surface, and percolates through innumerable minute cracks or larger fissures, dissolving away the chalk which it touches, and finally issues naturally in springs along the coast, or is pumped out artificially, a water which contains from fifteen to twenty-five grains per gallon of carbonate of lime.

Such an alteration in character depends, of course, upon the nature of the rocks which the water traverses, some rocks being easily soluble, others not.

The taking up of lime or magnesia in this way has the effect of rendering the water "hard," that is, increasing its soap-destroying properties. For many manufacturing processes this is a most undesirable quality, and we therefore find that many of the important industries of the country are located in districts where soft water is easily procurable.

The following are the formations which yield, as a rule, soft water: Igneous, metamorphic, Cambrian, silurian (non-calcareous), Devonian (non-calcareous), millstone grit, coal measures (non-calcareous), lower greensand, London and Oxford clay, Bagshot sands, non-calcareous gravels.

On the other hand the following geological formations almost invariably yield hard water: Silurian (calcareous), Devonian (calcareous), mountain limestone, coal measures (calcareous), new red sandstone, conglomerate sandstone, lias, oolites, upper greensand, chalk.

The manufacturing towns of Yorkshire and Lancashire obtain their supplies from sources which, even if the water had passed underground, would leave it comparatively soft, but this quality is fully secured by the character of the works, which consist of large reservoirs impounding the water which has principally run merely over the surface. For dietetic purposes, the quality of hardness, if not excessive, that is if it does not exceed twelve grains on Dr. Clark's scale (equivalent to twelve grains of bi-carbonate of lime per gallon) is not considered objectionable on physiological grounds. For ordinary domestic purposes and especially for personal washing and cleaning generally, soft water is infinitely preferable to hard, both in respect of comfort, efficiency, and economy.

Taking into account all the purposes for which water is used, it can hardly be questioned that a pure soft-water supply is, on the whole, preferable to a pure hard-water supply. The term "pure" is here used to imply the absence from the water of organic impurities as distinguished from the dissolved inorganic matters which have before been referred to. Except at producing hardness, the inorganic matters usually found in water are practically harmless; but organic pollutions may be of the most disgusting and dangerous character, those, for instance, which are the result of contamination with town sewage or of cesspool manure.

It is to avoid the risk of such pollution that many towns have in great measure been led to seek their sources of supply on elevated moorlands, above the level at which arable cultivation is carried on, and where it follows that there are no towns or villages, and the scattered population is very sparse. In this country the plough is rarely seen above the 800-feet contour, and, as it will not pay to cart manure to such an elevation, these high lands are merely used for the pasturage of sheep and the rearing of grouse.

Water obtained from such sources is practically, therefore, in the condition in which it falls from the clouds as snow or rain. The only impurity it may contain is a little organic matter derived from passing over the peaty soil, which often occurs on high moorlands, especially where the summits are broad and comparatively flat. This contact with peat and with growing heather gives a stain to the water to such an extent that, when seen in deep reservoirs, it is like dark coffee.

As seen in an ordinary white glass bottle or tumbler, the tinge is rarely deeper than a very faint straw color. There is nothing harmful in this coloring matter, because it is of purely vegetable origin, and to some extent it may be removed by storage in open reservoirs,

or running in open channels exposed to the air.

Many towns are so located in this country that it is practically impossible that they should obtain pure water supplies from elevated watersheds, on account of the enormous expense that would be entailed in the construction of the necessary works. Such places must be content to be supplied from rivers in their immediate neighborhoods, and which, having run their courses through many miles of highly manured lands and past thickly populated towns and villages, contain water which has necessarily become polluted by the washings from the lands and the sewage from the towns. Such sources as these would be inadmissible, but for the great rehabilitating process which nature silently carries on in a river, and to which chemists apply the term "oxidation." In this wonderful process the polluting organic matters which the water contains are converted by the agency of oxygen into harmless inorganic salts, and the water again becomes fit for the use of man.

This statement must, however, not be made without some reservation and explanation, because chemists of the very highest standing are not agreed as to the extent to which rehabilitation of the water is carried. This has, in fact, become quite a burning question, and the battle has been fought long and frequently over the water which is taken from the Thames, and delivered for consumption by the inhabitants of London.

The difference of opinion is now narrowed down into a small compass, and to outsiders it would appear that there is a chance, sooner or later, an agreement may be come to between the authorities.

As representatives of the two sides may be named Dr. Frankland and Dr. Meymott Tidy. Dr. Frankland admits that oxidation is effective in burning up, or converting into a harmless condition, even such foul contaminations as human sewage, if this is in a normal or healthy condition; but he contends that the virulent zymotic diseases are propagated by organized germs contained in the sewage which are indestructible, and which may travel scores of miles in a running stream without being deprived of their fatal potency.

Dr. Tidy contends, on the other hand, that there is no evidence of the existence of these animated germs, and affirms that a run of a few miles in a river fully oxygenated, and in which the pure water bears a sufficiently high ratio to the polluting matter, will suffice to render such water again fit for human consumption.

Dr. Frankland's theory is naturally a disquieting one, and his opponents certainly have facts in their favor, for London is undoubtedly one of the healthiest cities in the world, and its inhabitants have never been known to suffer from disease induced in the way suggested.

The "germ" theory is, however, making steady advances under the investigations and researches of competent men, and it is to be hoped and expected that if the historic germ is at last discovered, and exhibited to the incredulous gaze of Dr. Meymott Tidy, he, or some of his *confreres*, may speedily discover a method of scotching it before it has time to do any mischief.

It may now be convenient to describe shortly a few typical examples of the utilization of the different sources of supply which have been thus generally referred to.

I. Take first, such a case as that of Lancaster, whose works supply a population of between 30,000 and 40,000. The town is situated on the River Lune, about seven miles above its junction with Morecambe Bay, and is built upon a site which, rising from the river, varies in elevation from 15 to 200 feet above Ordnance datum, or mean tide level. The water is obtained from the high moorlands of Wyresdale, at a distance of eight or ten miles from the town, in a southeasterly direction. These fells, as they are locally called, constitute the extreme north-easterly portion of the watershed of the River Wyre, a small river which also falls into Morecambe Bay near the town of Fleetwood. That portion of the fells which is secured by Act of Parliament as a source of water supply for Lancaster, has an area of 2,700 acres, and an altitude varying from 850 to 1,800 feet above the sea.

The geological formation of the gathering ground is millstone grit, covered with scant herbage suitable for sheep pasturage, and heather. Interstratified with the beds of permeable grit stone there are layers of impervious shale

which, at various levels, throw out the water percolating downwards from the surface, in the shape of springs, and a number of these springs have been intercepted by small pipes communicating with mains laid along the hill side, and leading their combined waters to the south-west corner of the reserved area.

One of these mains forms part of the original works constructed under the superintendence of Sir Robert Rawlinson, C. E., C. B., in the year 1852; the other, which runs (broadly speaking) parallel to the first, but about 200 feet lower down the hill side, was laid six years ago, as part of an extension carried out by the writer.

The water derived from these is of necessity of the purest possible character, for the rain which feeds the springs falls upon the clean open moorland, and sinks at once into the millstone grit rock, in which it finds nothing to dissolve and cause hardness, and nothing to organically pollute.

The water issues from the springs in a bright sparkling condition, at a constant temperature of about 45° F.; it contains only one grain in 15,500 of solid matter, and its hardness is under 1° on Clark's scale.

This may be fairly regarded as an ideally perfect source of supply, and it has been an inestimable boon to the inhabitants, especially as it replaced water obtained from shallow wells in the town, polluted in the vilest possible manner by percolation from numberless foul and reeking privy pits and middens.

Between the fells and the service reservoir, which is situated on the town moor 240 feet above Ordnance datum, the country is intersected by several valleys, across which the water is conveyed in iron pipes.

At two intermediate points the pressure is broken by a small covered tank, and the water is never exposed to the open air from the time it sinks into the ground as rain or snow, and is drawn from the consumer's taps in the town.

Perhaps it may be as well to explain here that, when water is obtained from elevated watershed areas of this character, Parliament almost invariably insists upon "compensation" being made to the river for such abstraction. This compensation is secured by the construction of reservoirs somewhere upon the main river or its tributaries, in which water is stored in time of flood, and given out in a constant stream in times of dry weather, the assumption being that floods are utterly useless, if not damaging, to riparian owners and mill owners, whilst it is of advantage to every interest to have the dry weather flow increased in volume.

Thus, in the Lancaster case, whilst the Corporation have the right to take 2,000,000 gallons a day from the springs for the use of the town, they were put under the obligation to construct upon the River Wyre a reservoir capable of holding 185,000,000 of gallons, from which the millowners have the right to draw water according to their needs during the summer months. By means of such works, all the parties concerned are very greatly benefited.

II. The second type of utilization of sources which may be referred to, is that which is exemplified on so magnificent a scale in the works supplying Glasgow, and constructed from the designs and under the superintendence of Mr. John Fredrick Bateman, C. E.

In this case, advantage is taken of three natural lakes, viz., Loch Katrine, Loch Venachar and Loch Drunkie. The watershed area draining into these lakes is 45,800 acres in extent, and consists of unpolluted sparsely populated moorlands, the geological formation being of the silurian age.

Loch Katrine has a water surface of 3,000 acres, Loch Venachar 900 acres, and Loch Drunkie 150 acres. They are all of course supplied by the rain which falls upon the 45,800 acres, and as a considerable proportion of this area is of a peaty character, the streams which run down the mountain sides are frequently as dark as London Porter. By the deposit of the heavier parts of the peaty matter, and the bleaching action of the air, the water is drawn from Loch Katrine with only a faint tinge of color.

The two smaller lakes are utilized as compensation reservoirs, the artificial storage necessary being obtained by raising the original normal level of Loch Venachar 5 feet 8 inches with power to draw it down 6 feet, and by raising Loch Drunkie 20 feet, the raising in both cases

being done by masonry dams across the outlet valleys, furnished with draw-off sluices.

The storage for the supply of Glasgow is obtained by works which raised the normal level of Loch Katrine 4 feet and admit of drawing down 3 feet. Its capacity is, therefore, 3,000 acres of area, by 7 feet in depth, equivalent to nearly 1,000 million cubic feet, and competent to furnish 50 million gallons a day during a four months' drought.

The water surface in Loch Katrine is 360 feet above mean tide level at Glasgow. The conduit conveying the water to the city commences on the south side of the lake, about three miles from its western extremity, and runs generally in a southerly or south-westerly direction. At 26 miles from the Loch it discharges into an artificial reservoir of 70 acres in extent, and holding 500 million gallons near Mugdock Castle, the top water of this reservoir being 311 feet above mean tide at Glasgow. Two lines of three feet cast-iron pipes, one seven miles long and the other eight miles, convey the water to the city.

For thirteen miles out of the 26, between Loch Katrine and Mugdock, the conduit is formed by tunneling through very hard rock, such as whinstone, gneiss, and mica slate; the tunnels being seventy in number, nine miles of the remaining length is "cut and cover" work, and the rest consists of cast-iron or wrought-iron pipes across valleys.

The advantage of such a source of supply as Glasgow's is the facility and small cost with which the storage capacity necessary to furnish the requisite daily quantity for consumption and compensation is obtained.

In Loch Katrine, the narrow outlet from the lake had only to be dammed up four feet, requiring artifical works of the simplest character, entailing no risk or contingency in their execution. Having a flat area 3,000 acres in extent to begin with, a simple plank one foot high would have sufficed to impound 816,000,000 gallons. The desirability of securing such a reservoir site as this can only be fully appreciated by those who have had the responsibility and anxiety of forming large storage reservoirs, by the construction of high embankments across valleys. The relative amounts of labor and outlay in such reservoirs, and in cases like Loch Katrine, will be better realized in considering the next type.

III. The third type of works for the utilization of mountain watershed sources of supply is well exemplified in the Longdendale valley, where a number of reservoirs have, during the last thirty years, been constructed for the supply of Manchester. Here, instead of having a level plain 3,000 acres in extent as in Loch Katrine, upon which to commence as the bottom of a reservoir, was a valley with a fall along the bed of its main stream—the Etherow—of between 60 ft. and 70 ft. in a mile. Across this valley five embankments have been constructed of earthwork, one above another, forming five lakes with a combined water surface area of 462 acres. Beginning from the lowest part of the valley, the following is a list of the reservoirs, viz:

	Height of Bank. Feet.	Water area. Acres.	Capacity. Gallons.
Bottoms.......	66	50	407,000,000
Vale House....	55	63	343,000,000
Rhodes Wood..	75	54	500,000,000
Torside........	100	160	1,474,000,000
Woodhead.....	80	135	1,181,000,000
Total......	376	463	3,905,000,000

These embankments, which cost something like £100,000 apiece, have an aggregate height if placed one above another of 376 feet, and the quantity of water they impound is 3,905 million gallons. The raising of the water surface of Loch Katrine 5 feet would create the same amount of storage. The watershed area supplying these reservoirs is 9,300 acres, and the geological formation is millstone grit. The gathering ground is a portion of the western slope of the "backbone" of England, otherwise the Pennine range, upon which, over its whole length on both sides, many similar works are located for the supply of the manufacturing towns of Lancashire and Yorkshire. The rocks in this district are very much fissured and broken, and the rain falling upon the higher grounds percolates below the surface and re-appears as springs at lower levels. Advantage is taken of this by conducting the spring water along special channels into the Rhodes Wood reservoir, from

which the supply is taken by a conduit to the town.

Although the quantity of water yielded by the whole ground is that due solely to its area and the rainfall upon it, the fact of there being these springs renders it more valuable, because it implies that water which would have run off a district composed of harder and less pervious rocks, is here absorbed into the mass which thus acts as so much storage or reservoir space. The effect of this is to increase the dry weather flow of the streams, and to furnish water which is clear, cool and colorless. The average annual rainfall upon the 19,300 acres is about 50 inches, and the works utilizing this area are competent to provide 38,000,000 of gallons per day, of which 13,500,000 have to be delivered into the stream below the reservoirs as compensation water. Besides the five reservoirs above named, there are other large impounding and service reservoirs at Godley, Denton, Gorton and Prestwich. In the construction of these works enormous difficulties have been encountered, and at Woodhead, the highest reservoir of the series, the embankment, as at first made, was not watertight, so that a second trench had to be put down in which to build the puddled wall, and so much were the measures disturbed and distorted, that on the south side of the valley this trench had to be excavated to 167 feet below the surface of the ground, before sound and tight material was reached upon which the wall could be based.

The three types of works thus described may fairly be said to exhaust the methods of obtaining water from sources situated on elevated mountain gathering grounds. They are good examples of the gravitation system of supply, by which water is delivered at high pressure above the highest parts of the towns without any artificial pumping being required, the sun having done this work in the process of evaporation.

IV. We will now consider a case where the town to be supplied is at such a distance from high ground that the cost of bringing it through conduits or pipes by gravitation is prohibitive.

Take a town built along the banks of a river anywhere above the range of the tide. If this river flows through an agricultural district, and is thus not polluted by manufacturing refuse, and not seriously by either manure or sewage, it may be adopted as the source of supply. In this case the water will have to be lifted by artificial means to such an elevation as is necessary to command the whole town.

The water will also require filtration, because in running its course through the country the river receives the washing from the land, and in times of heavy rain, at all events, the water will be discolored and turbid through the presence of suspended matters.

The works for the supply of London are, in great part, of this character, the rivers Thames and Lea being the two sources.

Three hundred years ago water was obtained from the Thames at London bridge, and pumped by means of a water-wheel under one of the arches through wooden pipes into the streets and houses in the neighborhood. These works were continued in operation for 200 years, and were supplemented early in the 17th century by other pumping stations, taking water from the Thames at Charing Cross, Battersea, Vauxhall, and Hammersmith, all within the range of tidal influence.

In 1848 the Lambeth Water Company obtained powers to go into the non-tidal portion of the river above Teddington Lock, and by the year 1851 they were in a position to deliver water by means of a large steam-pumping establishment erected at Seething Wells.

In 1852 an Act was passed which made it unlawful for any company to supply water taken from the river below Teddington Lock, or from any of the tributaries within the tidal range. This led, finally, to all the companies drawing water from the Thames, so re-arranging their works as to have their intakes above Moulsey Lock, in order to be above the junction of the River Mole, which frequently brings down very dirty water.

Owing to the changes in the points of intake, the works of the London companies are divided into portions at great distances apart. Thus the Southwark and Vauxhall Company have at Battersea the reservoirs, filter beds, and pumping machinery constructed for the purpose of taking in water from the river at that point. They are well known to all Lon-

doners by reason of the tall stand-pipes which form a prominent object in the view from the trains running out of Victoria station.

These works are of so costly and extensive a character, that they could not be abandoned when the source of supply was changed to Hampton, 21 miles higher up the river, but the water abstracted there is pumped down to them through large cast-iron mains, to be filtered and distributed by the original machinery and mains.

In the case of the Lambeth Company, the water is taken from the Thames at Molesey, and sent down to Surbiton, which is the site of the filtering and pumping station, through a large brick conduit by gravitation.

From these circumstances none of the London works are good examples of the type now under consideration; but the following description will explain the nature of the works required for the utilization of such a source as the Thames above London.

First of all, then, provisions must be made to meet the difficulty of the water arriving at the intake in times of flood in a state of great turbidity or muddiness. This is met by the provision of large reservoirs, which are always kept full so long as the water is coming down in good condition, and the inlets into the river are closed, and they themselves are drawn upon when the water of the river is turbid.

These reservoirs used to be of smaller capacity than at present, and were worked as subsidence tanks, that is to say, the water (which might be somewhat turbid) was let in at one end and drawn off only from the surface at the other, the suspended matters causing the turbidity subsiding to the bottom during the water's slow passage through the tanks.

In London, since the works of the several companies have come under the official supervision of Sir Francis Bolton, very large sums of money have been spent in increasing the efficiency of these subsiding tanks by greatly augmenting their capacity, and practically changing their character into that of storage reservoirs.

In some of the works, these reservoirs are constructed at such a level that the water from the river flows into them by gravitation; in others they are elevated above the ground, and the water is pumped into them. In either case it is next delivered on to the filter-beds, the construction of which is shown very clearly in the most interesting pavilion erected in the Health Exhibition by the water companies. These filters consist of reservoirs or tanks made either by excavation in the ground or partial excavation, and partial embanking, as circumstances may dictate, having their sides sloped and pitched, or of vertical brick, stone, or concrete walls. The bottom is formed in many different ways, but it is always furnished with a number of open-jointed or perforated pipes or drains into which the water can pass, and by which it may be conveyed away to a pure water chamber or pump-well. Upon this floor the filtering material is placed, and consists of clean stones, flints, gravel, shells, and sand, arranged with the largest sized material at the bottom and the finest at the top.

Probably the oldest style of filter shown in the Exhibition is that designed by the late James Simpson, C.E., for the Chelsea Company, and it contains all the materials above-mentioned, and has a total depth of 6 ft. 3 in.

As, however, the really operative and effective portion of the filter is the sand, modern practice is tending in the direction of diminishing the depth of filtering material, and of omitting entirely several of the strata originally used. For instance, the New River Company's engineer exhibits a filter composed solely of 2 ft. of sand resting upon 6 in. of gravel, the total depth being only 2 ft. 6 in. In working the filters, the water is brought from the storage or subsiding reservoir on to the top of the sand, and stands from 2 to 3 ft. above its surface. It then percolates downwards through the filtering material into the drains below, and is run away to be pumped for distribution.

The speed of filtration may be adjusted by the head under which the filter is worked, that is, the difference in level betwixt top water and the draw-off. In some cases this is only 2 or 3 inches. The speed at which the water should pass vertically downwards through the sand used to be stated as 6 in. per hour, which gave 675 gallons per square yard per day of 24 hours, but the London companies

are now not filtering more than 450 to 500 gallons, or from 4 to $4\frac{1}{2}$ in. per hour.

The matter which is arrested by the filters consists principally of finely divided mineral matter washed from the surface of the land, of some vegetable and a trace of animal matter. These impurities are caught almost entirely in the top half-inch of the sand, which in course of time they choke and render impervious. The filter is then put out of use; the water is drawn off, and a skimming of the fouled sand is carefully removed and washed in apparatus which separates the light muddy matter and leaves the clean sand which is again put upon the filter. Of course, the washing process involves some loss of sand, and periodically additions have to be made of new material. After filtration, the water is in a fit condition to be pumped and distributed to the consumers.

Thus far we have been dealing with "above ground" sources of supply, obtained either by gravitation or by artificial pumping, under the four heads numbered—(1) being springs at high elevation, without storage; (2) being surface water from moorlands drawn from natural lakes; (3) being surface water from similar watersheds, impounded in artificial reservoirs; (4) being river waters filtered, and artificially pumped for supply.

There are in this country a few examples of hybrid schemes, that is, where water from comparatively low agricultural land is impounded in large reservoirs, and where it has to be subsequently filtered and pumped for distribution in the district. There may also be cases where water collected at a sufficient elevation to supply a town by gravitation has to be filtered before delivery.

We now come to the underground sources of supply, and one or two examples will suffice to explain how these are made available. We need not go far from home to learn all about one of the most important of these underground sources, for it lies under our feet in the chalk forming one great feature of the London basin.

London is actually built upon the tertiary deposits, which consist of Bagshot sands, London clay, and the sands and mottled clays of the lower strata; but underlying all these is a mass of chalk having the southern edge of its outcrop on the north of London about Hatfield, and the northern edge near Royston, and its southern outcrop extending from Croydon to Merstham. On the west the chalk reaches as far as Devizes, and on the north-east to near the coast of Norfolk and Suffolk. Portions of this vast area are no doubt covered by impermeable drifts of varying character, but there is still a very large tract of country upon which the rain which falls sinks below the surface, and goes to charge the great underground chalk reservoir below.

Possibly, the term "reservoir," though a common one, is a little misleading as applied to the chalk, because for water supply purposes, a large proportion of that which percolates into its mass is not recoverable by ordinary means. It is the water which circulates through the cracks and fissures which is really available, and not that which is held in the minute capillaries of the mass. Some chalk will contain 20 per cent. of its own bulk of water, and yet will not yield a drop of this under ordinary conditions.

Of the water which thus sinks into the chalk, a large portion finds its way out again into the bed of the river, another portion appears in the shape of large springs, such as those at Carshalton and Croydon, which go to form the River Wandle, by flowing over the edge of the impervious tertiaries.

Very rarely are there any streams where the chalk itself comes to the surface, but after heavy and continuous rains, streams do appear and flow for a time, and these are known as "bournes." As the chalk is 500 or 600 feet thick, a very large quantity of water is, however, left in it below the level of any of these natural outlets, and this water can be obtained in London by sinking wells through the overlying impervious beds of London clay, and allowing the water to rise, as in an artesian well.

There are a large number of wells in the London basin, and one of the metropolitan water companies, the Kent, obtains its supply exclusively from such wells. The ordinary practice is to sink a well from five feet in diameter upwards, and line the same either with brickwork or cast-iron cylinders down to the chalk. This will pass through superficial gravels, blue clay, bands of sand, mottled clay,

&c., and sometimes on the top of the chalk a band of flints will be found. Below the bottom of the well a boring is then made from 4 inches up to 15 or 18 inches in diameter, and lined with iron whilst in soft or much broken chalk, and left unlined where the material is more compact.

In those parts of London which are not elevated many feet above the level of the river, the water rises to very near the surface of the ground, and in some cases overflows; but wherever large quantities are required, resort must be had to artificial pumping so as to lower the level of the water in the well, and thus open out a larger cone of exhaustion in the chalk. Favorably situated chalk-wells yield as much as 2,000,000 to 3,000,000 gals. a day.

In many cases wells and mere borings have been put down right through the chalk to the upper greensand or gault below, and have yielded only a very small quantity of water. This arises from the fact before referred to, that the water circulates freely only in the cracks and fissures, and if some of these are not cut into by the boring, little water is obtained. The most certain way, therefore, of insuring a supply from the chalk, is by sinking a well down to below the permanent level of saturation, and then driving headings or adits in various directions, for the purpose of reaching some of these fissures. Many of the towns along the south coast of England are supplied by works of this character. It has been found that where the chalk of the South Downs has been undisturbed and is unfaulted, there are large vertical fissures which run, broadly speaking, from north to south, that is, at right angles to the coast. Along these fissures the water travels freely, and has its outlet at the base of the cliffs on the coast, and may be seen running down the beach in many places into the sea.

Parallel to the coast, the water is found to lie with its surface nearly horizontal, because of these permanent outlets, but on lines at right angles to the coast, the surface of the water rises rapidly inland, on a nearly uniform slope, so much so that, at six miles from the coast, it stands more than 200 feet above mean tide level. Advantage has been taken of these conditions at Brighton, and other places similarly situated, to sink wells and drive headings parallel to the coast, at about the level of low water.

At Brighton there are two such stations, one at Lewes-road, on the east, and another at Godstone Bottom on the west. These wells are both about a mile and a quarter from the sea, and headings are driven to a total length east and west, from Lewes-road, of 2,400 feet; and at Godstone Bottom, of 1,300 feet. In the first case, fissures are met with about every 30 feet, but as a rule these are small, and do not yield more than 100 to 150 gallons a minute. In the latter they are further apart, but some of them yield 700 or 800 gallons a minute, or over a million gallons a day. This water, being intercepted by the headings, is led to the respective wells, where, by means of suitable steam machinery, it is pumped up to the several service reservoirs supplying the different zones of the town.

The water so obtained requires no filtration. It is bright and sparkling, but of necessity hard, and although not objectionable for dietetic use, it is not well fitted for cooking or cleansing purposes, and would be utterly unsuitable for the manufacturing processes of Lancashire and Yorkshire, though thoroughly well adapted for paper-making.

In addition to the chalk, good supplies of underground water are obtained in the South of England from the Hastings sands and the oolites, and in the north from the new red sandstone, magnesian limestone, and other formations; but in all cases the works required for the utilization of these sources are very similar, consisting of wells, borings, and adits, with competent pumping machinery.

Comparing very generally "above-ground" supplies by gravitation with "under-ground" supplies involving pumping, there are advantages and disadvantages on both sides which may shortly be summarized as follows:

"ABOVE-GROUND" GRAVITATION SOURCES.

Advantages.	Disadvantages.
1. No pumping.	1. Distance from place to be supplied.
2. No filtration.	2. Peaty stain.
3. Softness.	3. Costly and somewhat risky impounding reservoirs.
4. Low charges for maintenance.	4. Large works involved to provide water "compensation."

"Under-ground" Pumping Sources.

Advantages.	Disadvantages.
1. Proximity of source to place to be supplied.	1. Annual charges for pumping.
2. Low first cost.	2. Hardness (generally.)
3. Few structural contingencies attending works.	
4. No filtration.	
5. No Compensation for abstraction of water.	

Water Supply for Fire Extinction.

BY J. H. GREATHEAD, M. INST. C. E.

When it is considered how vast is the havoc wrought by fire every year, and that we depend upon a supply of water, in all cases, to prevent much greater ravages, the importance of this subject will be at once recognized.

In London alone, it has been calculated on reliable data that the destruction of property in 1882 amounted to at least $2\frac{1}{4}$ millions sterling, and last year it was probably more; and it has been stated by a very good authority, Mr. Edward Atkinson, of the Boston Manufacturers' Mutual Insurance Company, that the losses by fire in the United States and Canada, in the five years ending January 1st, 1879, amounted to $82\frac{1}{2}$ millions sterling, while the cost of insurance companies and fire departments in the same period amounted to 55,000,000 more, or together to an average of 27,000,000 sterling per annum.

It is difficult for the mind to grasp such figures; the last, however, is about equal to the whole rateable annual value of the metropolis.

If such losses as these were inevitable, it would be of little profit to refer to them, but it is because I believe them to be to a large extent preventable that I have ventured to bring the subject of water supply for fire extinction before you.

In the remarks which I am about to make I purpose to refer largely to the case of this metropolis, as being likely to add additional interest to the general subject, and because the reasoning which applies to this will apply in a greater or less degree to all other similar cases.

It may be useful at once to define what are the requirements necessary to be fulfilled in a water supply for fire extinction purposes.

In order to reduce, as far as possible, the destruction of life and property by fire, the fire extinguishing service should have at hand—

(1) A copious supply of water.

(2) In close proximity to the property.

(3) Easily accessible.

(4) Having sufficient and reliable pressure.

In nearly all cities the water supply has been introduced and distributed without reference to the fulfillment of these conditions. The quantity of water required for the extinction of fires is so infinitesimal as compared with the quantity required for all other purposes, that, except where the conditions have been naturally favorable, the water service has been introduced, devoid of some, at least, of the qualities necessary to fit it for fire purposes. The result, in such cases, has been that mechanical contrivances have had to be provided in order to make good whatever deficiencies existed in the supplies, and dwellers in cities have become familiar with fire-plugs and fire-engines.

There are, however, some cities in this country where, the conditions having been favorable, the authorities having control of the water supplies have wisely availed themselves of Nature's gifts.

The most notable instances are those of Glasgow, Dublin, Liverpool, and Manchester. In all these cases the water supply is almost entirely by gravitation, and the result is that over the greater and most important parts of the cities there is a good pressure, and a copious supply of water which has been made easily accessible by the introduction of numerous hydrants in close proximity to the property in each place. Here, then, we have, as nearly as may be, in four of the most important cities of the United Kingdom, a fulfillment of the necessary conditions (as to water supply) for fire extinction.

An ordinary hydrant may be shortly described as a stop-cock on a water-pipe or main, to which hose may be attached for fire extinction or other purposes. If for fire-extinction, without the intervention of a fire-engine, the hose will, at its other end, be provided with a branch and nozzle. Upon opening the stop-cock the water from the main, or pipe,

will issue from the nozzle as a jet. The height of the jet will depend upon the pressure in the main, the quantity of water available, the length of hose employed, and the size and shape of the nozzle.

A fire-plug is a wooden plug driven tightly into a socket or opening in a water pipe under the road. When water is required for fire extinction the plug is withdrawn, and the water issues from the opening, either into the street, where it is usually received by a portable tank, or into a stand pipe inserted in place of a plug. It is obvious that plugs cannot be used where the supply is constant with a good pressure, and they have not been placed upon the constantly charged mains (the best existing supply for fire extinction) in the metropolis. Several forms of hydrants and a fire plug and stand pipe may be seen in the Water Companies' Pavilion in the Exhibition.

In order to obtain a good jet from a hydrant, it is necessary that the pressure of water at the hydrant, while flowing, should be about 65 lbs. per square inch. This will provide for overcoming the friction of the water in passing through an average length of hose, and will give a jet about 80 feet high from an inch nozzle. From the elaborate reports of the chief officer of the Dublin Fire Brigade, which he has kindly furnished to me, it appears that all the fires in Dublin, except those extinguished by small hand pumps, are put out by jets direct from the hydrants, and that the prevailing pressure is about 60 lbs. per square inch.

So much has been written and said about hydrants, and the advantages to be derived from their use, during the last twenty years, that it is hardly necessary for me to discuss their merits as compared with fire plugs. It is generally conceded that in all cases, whatever the water supply may be, whether constant or intermittent, high pressure or low, hydrants are superior to plugs as a means of letting the water out of the pipes. But it has been contended that so long as it is merely a question as between hydrants and plugs, the advantages of the former over the latter are not sufficiently great to justify any large expenditure upon them. When, however, the question becomes one as between hydrants and fire-engines, a wider view becomes necessary. Hydrants with a constant and copious supply and good pressure of water, are recognized as being incomparably better agents for extinguishing fires than fire engines, and the result of the introduction of hydrants into Manchester may be given in illustration. Mr. Bateman, the eminent engineer of the Manchester Waterworks, has stated publicly, on more than one occasion, that the introduction of hydrants with a good pressure of water has resulted in a reduction of the losses from fire in Manchester to a small fraction (viz., one-seventh) of what they were before the introduction of the hydrants. And, according to the report of Captain Tozer, the Superintendent of the Manchester Fire Brigade, the amount of property destroyed has only averaged 4.3 per cent. of that at risk during the last ten years, while it will be seen presently that in places having no efficient hydrant services the losses are many times greater. In Liverpool the fire brigade is a branch of the police. The water supply is mainly by gravitation from reservoirs (from 400 to 600 feet above the low parts of the town), and there are numerous hydrants. There are 3 steam and 14 manual fire engines. The population in 1881 was 548,650, and the area is $8\frac{1}{4}$ square miles. Of the 180 firemen, 170 do regular police duty. The annual cost of the brigade (average of three years, 1880–1–2) was £5,325, or £9 14s. per 1,000 of the population. The average annual number of fires in the same period was 219, but the loss by fire was not ascertained.

In Glasgow there is a good supply of water by gravitation; there are about 5,000 hydrants, and the majority of the fires are extinguished direct from the mains. There are 3 steam and 17 manual fire-engines. The 66 officers and firemen are supplemented by an auxiliary force of 52 policemen. The area of the city is $9\frac{1}{2}$ square miles, and the population in 1881 was 510,816. The cost of the brigade to the ratepayers in 1882 was £5,266, or £10 6s. per 1,000 inhabitants; while the average annual loss from fire in the same period was £110,000, or about £215 per 1,000 of the population.

In Manchester the supply is also by gravitation from resrvoirs at a considerable elevation (200 feet to 600 feet

above the Exchange), and there is a constant high-pressure supply. There are about 17,000 hydrants in the city and suburbs. Two steam and five manual fire engines are retained, but are seldom used. The population in 1881 was 341,500. The area of the city is $6\frac{3}{4}$ square miles, but the fire brigade extend their operations beyond the city. There are sixteen stations, and the annual cost to the ratepayers for the fire brigade is £3,547 (on an average of the three years, 1880–1–2), or equal to £10 8s. per 1,000 of the population. The average estimated annual value of property destroyed in those three years was about £80,000, or about £235 per 1,000 of the population.

In Dublin the supply of water is again by gravitation, and the pressure varies from about 40 lbs. to 80 lbs., being generally 60 lbs. when the water is flowing through the hydrants. There are numerous hydrants, and though there are 2 steam and 3 manual engines, they do not appear to have been used in the three years (1880–1–2), within the city. The brigade consists of 32 officers and men. The population in 1881 was 249,602, and the area of the city is 6 square miles, but the operations of the brigade are not confined to that area. The average annual cost of the brigade for expenses and wages (for the three years 1880–1–2) was £3,286, or about £13 3s. per 1,000 of the population. The estimated value of property destroyed averaged £31,144 per annum, or about £125 per 1,000 of the population.

In Birmingham the whole of the water supply is pumped, therein differing from the cases already referred to; but a system of fire hydrants has been recently introduced. The population (average of 1882 and 1883) is 411,690, and the area 13 square miles. The fire brigade consists of twenty-seven officers and men, and there are two stations and eight police stations, with apparatus. One steam and five manual fire engines are retained, none of which were used for fire extinction in 1882, and engines were used twice only in 1883. The total water supply is $11\frac{1}{2}$ million gallons daily, with a pressure of 40 lbs. to 60 lbs. per square inch. The annual cost of the fire brigade to the ratepayers (average of 1882 and 1883) is £3,250, or £7 18s. per 1,000 of the population, while the average annual loss in the two years was £10,931, or £26 11s. 8d. per 1,000 of the population, and this loss was equivalent to 3 per cent. only of the value of the property "at risk."

In Paris the water supply is partly pumped and partly by gravitation. Street hydrants have, to some extent, been introduced. In certain cases, where the pressure is sufficient, they are used without the intervention of fire engines, but the water supply is not such as to admit of this being done generally. It is intended, however, to increase the number of hydrants to 8,000, and ultimately to make them universal, and to dispense with fire engines. The total daily supply of water is about 82 million gallons. The population is 2,269,000, and the area 29 square miles. The fire brigade, numbering 1,743 officers and men, is an armed force lent by the Minister of War for the special service, and it is not called out for purposes of war. There are 11 barracks, 10 steam fire, and 80 small stations in addition to 40 look-outs, and there are 12 steam and 80 manual fire-engines. The annual cost of the fire-extinguishing service is £86,600 (average of two years, 1883 and 1884), or about £38 3s. per 1,000 of the population; but this cost does not include the rent and repairs of the barracks, quarters, &c., which belong to the Prefecture of the Seine. The estimated annual average losses for the three years 1880–1–2, were £431,300, or about £122 10s. per 1,000 of the population.

Having now described the operations, and their results in cities having efficient hydrant services, I propose to direct attention to some of the more important of the cities having no such services, and more particularly to New York and London.

In New York the water supply is very copious but it has not sufficient pressure for fire purposes without the intervention of fire engines. Hydrants have, to some extent, been introduced, and, it is stated, with benefit, as permitting more speedy access to, and preventing waste of, the water. The total supply is, according to the report of the fire department, about 100 million gallons daily; the population in 1880 was 1,206,300, and in 1881 probably 1,240,000. The area served by the fire brigade is about 39

square miles. In 1882 there were 50 engine companies, and 19 hook and ladder company stations, besides lookouts, fuel depots, and store houses. There were 57 steam fire, but no manual engines. In the period 1880–82 the average force was 939 officers and men, and the average annual expenditure was £288,190, or £230 8s. per 1,000 of the population. In the same period the average annual fire losses were £880,000, or about £710 per 1,000 of the population. The quantity of water used by the fire engines was about 40,000,000 gallons annually in the period 1880–2, or about 1-900th part of the total supply.

In London the whole of the water supply is pumped, and the average pressure is quite inadequate for fire extinction without the intervention of fire engines. A large number of observations were made all over the Metropolitan area by the Board of Works in 1876, and it was found that the average pressure was only about 30 lbs. per square inch, when there was no extraordinary draught on the pipes, such as that required for fire extinction; and it is not surprising that this should be so. The pressure given by the water companies is that required by statute, or, otherwise, by the customers of the companies, and even if they desired to do so it might be doubted whether, in the words of the Select Committee of 1876–7, the companies would be "justified by their constitution in incurring expenditure for fire purposes," for which purposes alone would it be necessary for them to increase their pressure.

The quantity of water delivered for all purposes is sufficient to meet the demands for fire extinction. There are, according to Captain Shaw's reports, very few cases of short supply, and constant supply is being gradually extended voluntarily by the water companies. Hydrants have been put down by the corporation throughout the city, and connected directly by branches with the constantly charged mains of the New River Company, and they have on several occasions been found useful, though the pressure is not such as to admit of fire engines being dispensed with in all cases. A few hydrants have also been recently introduced by the Metropolitan Board of Works in other parts of the metropolis.

In the matter of pressure, however, as already stated, the general metropolitan water supply is undeniably deficient. There is a copious supply of water in close proximity to the property to be protected, but it cannot be brought to bear upon a fire without the intervention of fire engines.

The population of the metropolis in 1881 was 3,814,571, and the Metropolitan Board of Works area is about 121 square miles, including the city's one square mile. There are fifty-five land fire stations, 12 street, 127 fire escape, and 4 floating stations; and the brigade consists of 588 officers and men. The annual average cost of the fire brigade for the three years 1880–2 was £99,880, or £26 4s. per 1,000 of the population. It is somewhat difficult to arrive at the value of the property destroyed by fire in the metropolis, but a calculation based upon the contributions of the insurance companies to the support of the fire brigade, and upon evidence given by Captain Shaw and others before the Select Committee on the Fire Brigade in 1877, would make it appear that in 1882 the value of insured and uninsured property destroyed by fire was probably considerably in excess of 2¼ millions sterling, or about £588 per 1,000 of the population. As compared with the efficiently hydranted places already referred to, it will be seen that the cost of the fire extinguishing service, and the fire losses, are very high in London. This will be made very apparent upon an inspection of the appended Table A, which gives, in addition to the cost of the fire services and fire losses in the several places referred to, a statement of what the cost and losses would be in the metropolis, were the rates of cost and loss the same as in the other places.

It will be asked why the metropolis should have been allowed to remain, year after year, subject to the preventible drain of wealth indicated by these figures? The reply is, that the past and existing state of things have not been submitted to in ignorance or willingly, but the difficulties surrounding the subject in the metropolis have been practically insurmountable.

More than twenty years ago the Select

Committee on Fires in the metropolis directed attention to the extraordinary facilities for extinguishing fires then existing in Liverpool, Manchester and Glasgow, and to the efficiency and small cost of the fire services in those places; and, more recently, in 1876–7, the Select Committee on the Metropolitan Fire Brigade, having heard evidence as to the advantages of the hydrant systems referred to, recommended that hydrants should be put down in the metropolis at once wherever a constant supply was given, and that the water supply should be improved so as to give constant service everywhere and increased pressure. But it was found that to comply with these recommendations a permanent expenditure of £337,000 per annum beyond the cost of the fire brigade would be involved. Of this annual sum about £150,000 represented the increased cost of pumping alone; and since the quantity of water required for fire purposes is infinitesimal as compared with the quantity supplied for all other purposes, it is obvious that this expenditure of power, if the whole had to be pumped to the requisite height, would be out of proportion to the result obtained. I have made a calculation, based upon the relative quantities and upon the evidence given before the committee, from which it appears that for the purpose of discharging water through a hydrant upon a fire in this way, about 170 horse-power would be required for every gallon of water thrown. And there would be the attendant disadvantages that all the house fittings would have to be altered and strengthened, and the mains and pipes would have to be taken up, and relaid of greater size and strength, and at enormous inconvenience to the householders and the traffic in the streets; and the pressure would, in the greater part of the metropolitan area, be inconveniently great. This proposal also involved the great disadvantage that it could not be carried out until the water companies should have been ranged under one control.

As long ago as 1862, the late Mr. James Easton, who held the view that no satisfactory supply of water for fire extinction with constant high pressure could be secured in connection with the ordinary domestic supply, proposed to lay down a completely new set of mains to be used exclusively for fire purposes, but the cost would have been enormous. His estimate was £72,000 per square mile, and his proposal only extended to forty square miles of the metropolis. This area alone would have involved an annual cost for interest and working expenses of £150,000. A somewhat similar proposal, but with the addition that the water was to be taken from the chalk formation at about 15 or 20 miles from the center of London, instead of from the water companies' mains, as was proposed by Mr. Easton, and that the supply was to be used for potable and culinary purposes after being pumped to the greatest attainable elevation, in order that it might have sufficient pressure for fire extinction purposes, was put forward by the Metropolitan Board of Works, on the advice of Sir J. Bazalgette, Sir F. Bramwell, and Mr. Edward Easton, in 1877. It was estimated that the introduction of this system of hydrants would have resulted in an annual saving of £60,000 in the existing expenses of the fire brigade. This scheme, involving a dual supply to every house, was taken to Parliament, but was withdrawn; and, in their annual report of 1878, the Board said that they "came to the conclusion, in view of the disfavor with which the scheme appeared to be regarded by most of the local authorities of the metropolis and others, not to bring it before Parliament again in the following session." Looked at purely from a fire extinction point of view, there is one great objection to all the proposals that have been hitherto made, viz., that owing to the great variations of level in the metropolis, there would, in many localities, be insufficient pressure, while in others the pressure would be excessive.

In any water supply for fire purposes, it is certainly desirable that the pressure, in addition to being sufficient, should also be moderately uniform in the hose, whatever may be the elevation of the locality. This uniformity is practically obtained at present by the use of fire engines, but with the great drawback that the power requisite for giving the pressure is not available on the instant that the occasion for its use is discovered. The diagram B on the wall illustrates among other things the result of the vigorous efforts made by the fire brigade to reduce this

evil to a minimum. It shows that since the year 1870, when Captain Shaw first began to publish the distances traveled by his engines—the distances run have increased from 11 miles to $34\frac{1}{4}$ miles (in 1882) per fire. The number of journeys made has increased from 8,000 to 29,000, and the total distances run from 22,000 miles to 66,000 miles in the year.

According to the evidence given before Sir H. Selwyn Ibbetson's Committee in 1877, the fire engines were then only used for pumping at about one-fifth of the fires. If that was still the case in 1882, then it follows that for each time the engines were used for pumping upon a fire they must have run, on an average, 172 miles.

When it is considered under what unfavorable conditions, and how uselessly the journeys are often made, some idea may be formed of the superiority of a system of hydrants where the power, as well as the water, is always on the spot ready for instant application. The same diagram illustrates also another feature of the fire brigade service, viz., the growth of its cost from the commencement of the old fire engine establishment in 1833. It will be seen that the growth has been, and is, very rapid as compared with the growth of the population. In the first year of the Metropolitan Board of Works' administration of it the cost of the brigade was under £41,000; in 1882 it was £106,552, or an increase in the period of sixteen years of 160 per cent., while the population increased only 28 per cent., and the number of fires 44 per cent.; and in the year 1883, the cost had further increased to over £115,000. It must not be supposed for a moment that this increase is to be regarded as unnecessary under existing conditions. The cost of the London Fire Brigade is, thanks to Captain Shaw's admirable organization, still small, as compared with some other unhydranted cities. In New York, as already stated, the cost is very much greater for less than a third the population and area. There the average annual cost for the three years, 1880–3, was over £288,000, and it appears to be growing almost as rapidly as that of London, though, on the other hand, the population there is growing more rapidly. Paris, also, another practically unhydranted city, with half the population, spends proportionately more than London for fire extinction.

The question of the cost of fire extinction again, is not the sole consideration; behind that there is the question of fire loss, or the destruction of property by fire, and the loss of life. Putting aside the last and highest question as being one not altogether dependent upon the extinguishing service, I propose now to direct attention to the question of fire losses as affected by the absence or presence of efficient hydrant services.

In describing the hydranted cities I have already given the fire losses in four of them, viz., Glasgow, Manchester, Dublin and Birmingham, in accordance with the published estimates, and I have shown that the losses are—in Glasgow, £215; in Manchester, £234; in Dublin, £125, and in Birmingham £26 11s. per 1,000 of the population. In the case of New York the losses are published in detail, and amount to about £710 per 1,000 of the population, as compared with £588, the loss in the metropolis as estimated by myself.

The Table A has been prepared in accordance with the facts I have stated; but in order to give the figures a practical bearing in the case of the metropolis, I have added two columns which give the costs and losses of a place having the population of London, at the same rates as each of the places considered. It will be seen that the annual cost of extinction by hydrants, if it were at the same rate as Liverpool, Glasgow, Manchester and Birmingham, would be from £30,000 to £40,000; and at the same rate as Dublin, £50,000; while, if it were at the same rate as New York, the cost would be £886,000, instead of £99,880, the average annual cost in London in the years 1880–2.

The diagram H (shown on the wall) has been prepared from Captain Shaw's table, already referred to, and it seems to place the value of efficient hydranting in a very striking light. From the table referred to have been plotted the figures, giving the cost of the fire brigades in a number of important towns at the date of the compilation of the table (in 1877). The cost in the hydranted cities, viz., Glasgow, Liverpool, Manchester and Dublin has been shown in red. The blue line shows the cost in

TABLE A.—ANNUAL COST OF FIRE EXTINCTION, AND ANNUAL AMOUNT OF FIRE LOSSES, IN SOME HYDRANTED AND UNHYDRANTED CITIES.

Average of Three Years, 1880, 1881, 1882.

	Population, 1881.	Area, Square Miles.	Cost of Fire Brigade.	Cost of Fire Brigade per 1,000 Inhabitants.	Cost of Fire Brigade of Metropolis at same rate.	Loss.—Property destroyed by Fire.	Loss. — Property destroyed by Fire per 1,000 Inhabitants.	Loss of Property in Metropolis at same rate.
* HYDRANTED.								
			£	£ s.	£	£	£ s.	£
Liverpool..........	548,649	8.28	5,325	9 14	37,000	—	—	—
Glasgow...........	510,816	9.55	5,266	10 6	39,290	110,000	215 7	821,542
Manchester........	341,508	6.7	3,547	10 8	39,670	80,180	234 16	895,644
†Dublin............	249,602	6.0	3,286	13 3	50,200	31,144	124 16	476,050
Birmingham, 1882-3.	411,689	13.15	3,250	7 18	30,115	10,931	26 11	101,287
* UNHYDRANTED.								
London............	3,814,571	121	99,880	26 4	99,880	2,242,400	587 19	2,242,400
New York.........	1,240,000	39	288,190	232 8	886,490	880,000	709 14	2,707,150
‡Paris, 1883-4......	1,269,023	39	§86,600	§38 3	145,500	‖431,300	‖192 10	734,300

* The terms "hydranted" and "unhydranted" indicate the presence or absence in each place of a complete system of hydrants which are used for fire extinction without the intervention of fire engines.
† The cost of the Fire Brigade has been reduced from £3,616 in 1880, to £3,053 in 1882.
‡ A large number of fire hydrants have been put down, and some have been used without the intervention of fire engines, but the average pressure is not such as to admit of this being generally done.
§ Average of 1883 and 1884, exclusive of rent and repair of quarters, barracks, &c.
‖ Average of 1880, 1881, and 1882.

a number of American cities. Paris and London, having populations respectively twice and over three-fold as great as New York, are not shown, but from the table, and the remarks upon it it will be gathered that in both those cases the cost would be far above the rates shown by the red color, which has been extended to embrace a place of the size of New York.

In the foregoing remarks I have simply taken population as the basis of comparison between the several places. And, I do not pretend to say that there are not exceptional considerations apart from the question of water supply, such as areas, character and proximity of buildings, habits of people and so on, which would, and no doubt do, materially influence results, but the distinction between the hydranted and unhydranted places is so broad and marked where the places are of such different characters on the one hand as Glasgow, Liverpool, Manchester and Dublin, and on the other hand, as London, New York, Paris and Birmingham, that it must appear to all that the absence or presence of efficient hydranting far outweighs any other consideration.

It now remains for me simply to add that, having for some years devoted much study to the subject, I believe that, notwithstanding all the difficulties, only the chief of which have been adverted to here, there are methods—or perhaps I ought rather to say there is a method—by which such cities as London, New York, and Paris may be efficiently hydranted at a comparatively small cost, and practically with very trifling inconvenience, which method I have already described in papers read at the last meeting of the British Association, and before the Institution of Mechanical Engineers. It is, however, impossible, within the

limits of a single paper, as must be sufficiently obvious, to discuss the whole question; I, therefore, content myself on this occasion by advancing the proposition that efficient hydrants form, as far as our experience goes, the only effective weapon with which fire brigades can successfully cope with fires.

On the Purification of Water by Iron on a Large Scale.

BY W. ANDERSON, M. INST. C. E.

In January, 1883, in a paper on the Antwerp Waterworks, read at the institution of Civil Engineers, I described the application of Professor Bischof's method of filtration, through a mixture of spongy iron and gravel to the purification of the waters of the River Nethe. The eighteen months' additional experience gained has shown that, so far as the purification of the water is concerned, Professor Bischof's process leaves little to be desired, but the working of the system has been costly, and the area of land required, as well as the quantity of iron necessary, has, in the case of the Antwerp water, at any rate, proved very much beyond the inventor's expectations.

The increased demands of the town rendered it necessary to extend the arrangements for purifying the water, and it became my duty to advise the directors of the company on the best means of doing this.

The extension of Professor Bischof's method would have involved so great an outlay, that after trying, unsuccessfully, many experiments on direct filtration through unmixed iron at high rates of flow, I determined to adopt a plan first suggested to me some years ago by our chairman, Sir Frederick Abel, of agitating the water to be purified with iron instead of attempting to filter it. The object in either case was to expose the water as much as possible to an extended surface of iron, consequently, any plan by which the iron could be made to keep itself clean by rubbing against itself continually, would seem to be a more rational way of attaining this object, than of trusting to a partial filtration through a more or less spongy material.

The obstacle to trying Sir Frederick Abel's method at a much earlier date, was the belief entertained by Professor Bischof that a contact of about 45 minutes was necessary to ensure complete purification, and any such time would be fatal to mechanical means of performing the work. The late Professor Way and Mr. Ogston, it is true, had shown that with very finely divided iron the effect was much more rapid, but there was still a doubt about its permanence.

In the autumn of last year, a revolving cylinder, 4 ft. 6 in. in diameter, and 5 ft. 6 in. long, was adapted to try Sir Frederick Abel's system. It was fitted with inlet and outlet pipes, and with shelves or ledges for scooping up the iron, raising it to the top of the cylinder, and then letting it fall through the water.

At first I began to run water through at 12 gallons per minute, which gave a contact of about 45 minutes, but I found that at this rate the water was very heavily charged with iron; I gradually increased the quantity to 30 gallons per minute, and then found that 1.20 grains of iron were dissolved per gallon, or about twelve times more than experience at Antwerp showed to be necessary. The flow was increased to 60 gallons, and even then 0.9 grains per gallon were dissolved.

The experiment looked so hopeful that I fitted much larger pipes to the apparatus, and having made some other dispositions connected with maintaining a uniform distribution of iron in the cylinder, and preventing it being washed away by the comparatively rapid current that would be possible, I sent the "Revolver," as it came to be called to Antwerp, where it was put to work at the end of last February, and has continued to operate ever since.

The head available for forcing the water through the "Revolver" is, at Antwerp, limited to 5 feet, but by fitting very large pipes I have managed to get 166 gallons per minute through; this gives a contact of about 3½ minutes, and is so amply sufficient that I feel sure that, even for the waters of the Nethe, much less time will be adequate.

The charge of iron is about 500 lbs., and the quantity taken up by the water, including impurities and very fine iron washed away, during a run of thirty-three days was 0.176 grains per gallon.

By making suitable arrangements, and choosing a favorable time with respect to the demands of the town, we were

able to obtain samples of water that had been purified by the "Revolver" only, and after proper exposure to the air, followed by filtration through one of the large sand filters, the result obtained has been that the color was very little different from distilled water, the free ammonia was reduced from 0.032 grains per gallon to 0.001, and the albumenoid ammonia from 0.013 grains to 0.0045.

The "Revolver" turns at the rate of about $\frac{1}{3}$ revolution per minute, and requires scarcely appreciable power. The area occupied by apparatus for dealing with 2,000,000 gallons per day is 29 feet by 24 feet, and it can be introduced into any existing system of filters, for by enlarging the inlet and outlet pipes to a suitable diameter, a head of some 12 inches will suffice to pass the water through.

It can easily be arranged so as to be used or not, as the state of the water to be purified may warrant, and the consumption of iron being only about 20 lbs. per million gallons is quite an insignificant expense. It will be found to remove all color from water whether caused by peat or clay, and will facilitate the action of sand filters by the peculiar curdling effect the iron has on the impurities.

During the experiments made at Erith, it was noticed that considerable quantities of gas collected in the upper part of the "Revolver." On collecting this gas it was found to extinguish a lighted taper instantly, and on analysis was found to contain only 8 per cent. of oxygen.

It was observed from the first that the animal and vegetable life which was so abundant and troublesome in the natural waters of the Nethe, lying over the spongy iron filters, had quite disappeared in the water, otherwise in exactly the same circumstances lying over the sand filters, and I always supposed that this was due chiefly to mechanical filtration through the spongy iron having separated all the germs, spores and seeds which come to life above it. But, during the recent hot weather, it has been found that the water from the "Revolver," though it contains all the impurities of the natural water, has been modified by the action of iron to such an extent that neither animal nor vegetable life is apparent over the sand filters. Without presuming to draw very wide inferences from this fact with reference to the action of iron upon organisms connected with disease it may, at least, be pointed out that the absence of visible life in water treated by iron on a large scale confirms, in a great measure, the experiments of Dr. Frankland, Dr. Voelcker, Mr. Hatton, Professor Bischof, and others. It is due to the last-named gentlemen to state that to his persistent advocacy the introduction of iron as a purifier is mainly due. It must be borne in mind that the system does not depend on filtration only, but, first, on a process of exposure to iron, which decomposes the organic matter, and kills living organisms; and, secondly, on simple filtration, which merely separates the noxious matters which had been previously attacked by the iron. The waters of the Nethe are exceptionally bad, and heavily charged with impurities, so that the test both of Professor Bischof's and Sir Frederick Abel's systems has been very severe.

THE Russian review, *Russkaya Starina* and the *Journal* of the Russian Chemical and Physical Society have lately devoted some attention to the first steam engine that was made in the Russian Empire, in 1763, at the ironworks of Barnaoul, in Western Siberia, by a mining engineer, Polzunoff. It appears from M. Woyeikoff's description of this steam engine, the model of which, *Nature* says, exists still at Barnaoul—both reviews have figured it on plates—that Polzunoff's engine was a reproduction of the "fire-engine" of Newcomen, with some original improvements. Thus, it has two cylinders, instead of one, and, instead of the beam, Polzunoff made use of a wheel which received the chains of the pistons, and transmitted the circular movement, transformed again into a rectilinear one, to a pair of bellows, used for blowing air into a high furnace. The distribution of vapor was automatic, as in Newcomen's engine, but with several improvements. The engine, which had cylinders 9 ft. long and 9 in. in diameter, worked during two months from May 20th, 1766, and 3100 cwt. of silver ore, yielding 5 cwt. of silver, were melted with its help. But Pulzunoff did not see his engine at work, as he died from consumption four days before. He was a remarkable man for his time. In his theoretical remarks about "Air, Water, and Vapor," he notices also that physicists are not agreed as to the origin of heat, some of them seeing in it a much-divided, fine moving matter, while others "see the origin of heat in friction and in the vibratory motion of the particles inaccessible to our senses, of which the bodies are constituted." He obviously quotes here the words of Lomonosoff, who stated in these words the mechanical origin of heat in his little-known memoir, written as an instruction to Tchitchagoff's Polar Expedition.

SIZE AND INCLINATION OF SEWERS.

By ALFRED EDWARD WHITE, Assoc. M. Inst. C. E.

From Selected Papers of the Institution of Civil Engineers.

There is no doubt that each of the two systems of sewerage, the separate and the combined, possesses certain advantages and certain disadvantages, as compared with the other; there being some conditions under which the former system may be adopted with the greater benefit, and other conditions under which the latter is the more applicable. An advantage of some importance, however, which the separate system possesses over the combined system, is that of allowing of the use of sewers of a smaller size.

As a rule, the smaller a sewer (within certain limits) the better, provided it is large enough to deliver the maximum quantity required to be disposed of; and the smaller the excess of the maximum flow over the ordinary flow, the more efficient may the sewer be made for the conveyance of the ordinary flow. A sewer constructed to receive the whole of the surface water in addition to the sewage, will not, with the dry-weather flow consisting of sewage only, work as efficiently as a smaller sewer, constructed to convey the sewage with only a limited quantity of surface water. The larger sewer is so much in excess of the requirements of the dry-weather flow, that it will not under ordinary circumstances be self-cleansing to the same extent as the smaller sewer, while the smaller may also be more efficiently flushed with a moderate supply of water.

It probably is necessary in almost all cases (in order to avoid an unreasonably complicated arrangement of branch drains) to admit the water from back roofs and back yards to the sewers, even where there are separate drains for surface water; but the greater the quantity so admitted the more it will tend to neutralize the advantage above referred to.

To determine the volume of the dry-weather flow in any sewer is a comparatively simple matter, if sewage only be admitted to it, as such volume may be considered equal to the amount of the water-supply; which amount is usually known with sufficient accuracy, and for an average town may be taken at 25 gallons per head per day. In making provision for the maximum dry-weather flow of sewage, it is usual to assume that one half the daily quantity is discharged in from six to eight hours; if, therefore, the daily quantity be assumed at 25 gallons per head, the maximum flow will be at the rate of 12½ gallons per head in (say) six hours, or about 2 gallons per head per hour.

The amount of rainfall, which it is necessary to provide for in the sewers, is a much more difficult matter to determine, and one which seems to be often under-estimated. In the first place it is necessary to estimate the amount which the sewers should be capable of receiving above storm-overflows; and in the second place the amount which they should deliver below such overflows. To prepare for the heaviest rains in this country is out of the question, considering the excessive falls which occasionally take place. The rate of rainfall to be provided for above the overflows should be determined with due regard to the degree of risk of such rate being exceeded, and to the amount of inconvenience or damage which would be caused in the event of its being exceeded; but to incur a great expense in constructing large sewers, merely to avoid the probability of their overflowing and causing a small amount of damage, once or twice in a generation, would be unreasonable. Such expense, however, might be justified where the probability of overflow, and also the damage likely to ensue, were great. With regard to the sewers below storm-overflows, their capacity should be sufficient to avoid overflows of such frequency and amount, as would seriously pollute the watercourses or rivers receiving the overflows.

Under the separate system the only rain which should find its way to the

sewers is that falling upon back roofs and back yards, and the quantity may be estimated from the area of such roofs and yards, together with the maximum rate at which rain falls. The above area may be taken at an average of 500 square feet for a house occupied by five persons, or 100 square feet per head of the population, and it may be assumed that the entire rainfall upon such area is discharged into the sewers.

The published rainfall tables, of the description required to determine the maximum rate at which there is a probability of rain falling, are of a very meager character. Observations of rainfall are not usually taken at shorter intervals than twenty-four hours, and the duration and amount of most heavy rains consequently are not recorded. In the volumes of "British Rainfall,"* there are, however, tables giving all the exceptionally heavy falls reported by observers in various parts of the United Kingdom, and by these tables some valuable information on the subject is given. Taking the records of the three years, 1880, 1881 and 1882; there are reported fifty-seven falls at a rate of over 1 inch per hour, forty-two over $1\frac{1}{4}$ inch, thirty over $1\frac{1}{2}$ inch, eighteen over 2 inches, six over 3 inches, and two over 5 inches per hour. The heaviest fall reported was at the rate of 5.80 inches per hour, and it continued for thirty minutes. Regarding these records, the impracticability of providing for the heaviest falls is obvious; it seems to the author, however that a fall at the rate of $1\frac{1}{4}$ inch per hour should in average cases be provided for, in sewers which are not relieved by storm-overflows; and for the purpose of future calculations it is assumed that such sewers should be capable of receiving a fall of this amount. It should be stated that many of the above-mentioned forty-two falls, which exceeded $1\frac{1}{4}$ inch per hour, were of such short duration that they would not cause sewers, capable of discharging this amount, to overflow, as the capacity of sewers, independent of their discharging power, is considerable.

The available statistics, of the character necessary to determine the amount of rainfall which it is desirable to provide for in sewers below storm-overflows, are, for the purpose required, of a more satisfactory nature than those above referred to. "British Rainfall" for the year 1880 contains a very useful table, contributed by Mr. Baldwin Latham, M. Inst. C. E., prepared from the records of a self-recording rain-gauge at Croydon; such table giving the quantity, duration, and rate per twenty-fours hours, of all falls of rain of any importance, from March, 1879, to April, 1881. Some similar information is afforded by the records of a self-recording rain-gauge at Camden Square, London, which have very kindly been placed at the disposal of the author by Mr. Symons. As these records have not before been tabulated, a table prepared from them, giving particulars of the important falls of 1881 and 1882, is appended to this paper.

Table 1, which is an abstract from the above-mentioned tables, shows the number of times certain rates of rainfall were exceeded in two years; also the aggregate duration of the falls exceeding these rates.

TABLE I.

	Rate of fall in fractions of an inch per hour.	Number of times rate was exceeded in two years.	Aggregate duration of excessive falls in hours.
Croydon Records	$\frac{1}{4}$	38	$20\frac{1}{4}$
	$\frac{1}{6}$	78	45
	$\frac{1}{8}$	108	73
	$\frac{1}{12}$	154	$115\frac{1}{2}$
Camden Square Records	$\frac{1}{4}$	59	$11\frac{1}{2}$
	$\frac{1}{6}$	99	$35\frac{3}{4}$
	$\frac{1}{8}$	136	$71\frac{3}{4}$
	$\frac{1}{12}$	202	119

From this table may be obtained, approximately, the number of times that storm-overflows would come into action with sewers capable of discharging various amounts of rain, and also the aggregate duration of the overflows. As, however, a number of the falls included were of very short duration, and in many cases would not be simultaneous over the whole drainage area, it may be assumed that some of them would not cause overflows, and that the duration of the overflows caused by others would be reduced; and to compensate for this a deduction of (say) 20 per cent. should be

* "On the distribution of rain over the British Isles." Compiled by G. J. Symons, F. R. S.

made from the figures in Table 1. Now, taking a sewer capable of discharging a rainfall of $\frac{1}{8}$ inch per hour, and making the required deduction, the number of overflows during two years, according to the Croydon records, would be eighty-six, and according to the Camden Square records one hundred and nine, and their aggregate duration, in each case, about fifty-eight hours; or during one year the number of overflows would be forty-three and fifty-four and a-half respectively, and their duration, in each case, about twenty-nine hours. Overflows to this extent in most cases, and probably to a considerably greater extent in many cases, would be admissible, and for the purpose of future calculations it is therefore assumed that sewers below storm-overflows should be capable of discharging $\frac{1}{8}$ inch of rainfall per hour.

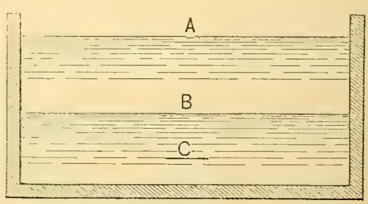
It is of interest to notice that of the rainfalls at Croydon and Camden Square, during the above period, none amounted to the maximum quantity which would be received by sewers capable of discharging $1\frac{1}{4}$ inch per hour. Eight falls were in excess of one-half the capacity of such sewers, forty-six of one-quarter, and one hundred and sixty-eight in excess of one-eighth their capacity. The heaviest fall, which was at Camden Square, continued for ten minutes at the rate of 1.68 inch per hour; this, however, taking into consideration the shortness of its duration, was about 12 per cent. below that which sewers capable of discharging $1\frac{1}{4}$ inch per hour would receive. The fall second in importance was at Croydon, and continued for ten minutes at the rate of 1.34 inch per hour, this being about 30 per cent. below the amount the sewers would receive.

Upon the area before mentioned as that which may be assumed to be covered, per head of the population, by back roofs and yards, viz., 100 square feet, a rainfall of $1\frac{1}{4}$ inch would produce 65 gallons; and as the maximum volume of the sewage proper, in average cases, as already determined, is about 2 gallons per head per hour, a total of 67 gallons per hour should be provided for in sewers which are not relieved by storm-overflows. With regard to sewers below storm-overflows, the volume to be provided for, per head per hour, according to the foregoing conclusions, is a rainfall of $\frac{1}{8}$ inch on 100 superficial feet, or $6\frac{1}{2}$ gallons, and 2 gallons of sewage, making $8\frac{1}{2}$ gallons.

Sewers should, where possible, be constructed with such inclinations as will render them self-cleansing with the ordinary flow of sewage; and where this is impracticable, the inclination should at least be sufficient to give a self-cleansing velocity with the assistance of flushing.

As to the velocity necessary for self-cleansing purposes, authorities differ somewhat. It seems to be usually considered that small sewers require a greater mean velocity of sewage flow than large sewers, but the grounds upon which this assumption is based do not seem very clear. The bottom velocity is that upon which the self-cleansing properties depend; but how is this velocity to be determined? The size, form, gradient, and depth of flow of a sewer being given, there are several reliable formulas for calculating the mean velocity, but not so the bottom velocity. One authority states the bottom, mean and surface velocities to be nearly as 3, 4 and 5, and others express the ratio by figures nearly corresponding with these. It appears to be assumed that these proportions apply under all circumstances; but that this is a mistaken assumption, the author would submit, may be proved as follows:

If a trough be taken, as shown by the annexed diagram, in which the water is up to A, then, according to the above rule, if the velocity of flow at A be represented by 5, that at B, half-way down, will be about 4, and at the bottom 3, while the velocity at C, mid-way between



the bottom and B, will be about $3\frac{1}{2}$. Now if the water be only up to B—that is to say, of half the depth before assumed—and the inclination be increased so that the mean velocity is the same as before, then the velocity at C, it being about the mean, will be 4. Thus in the former case

the velocity at C, which was $3\frac{1}{2}$, was less than in the latter, the mean velocity in each case being the same. How then will the bottom velocities in the two cases correspond? The velocity of the bottom water is affected by three forces: I. Its own gravity, due to the inclination of the trough. 2. The velocity of the water directly above. 3. Its friction upon the bottom of the trough. The first force, that of gravity, is greater in the latter case, or with the shallow flow, as the inclination is greater; the second force, that of the water above, is also greater in the latter case; for, taking any point above the bottom, as, for instance, the point C, the velocity at that point is greater in the shallow flow. The third force, that of friction, upon the bottom of the trough, is equal in each case. Both the force of gravity, and the greater velocity of the water above, tend to give the bottom-water a greater velocity with the shallow flow, and it is therefore evident that the difference between the mean and the bottom velocity is greater with a deep flow of sewage than with a shallow flow, or, under ordinary circumstances, with a large sewer than with a small one. It would therefore appear that the mean velocity necessary to render sewers self-cleansing is greater with a deep flow than with a shallow flow.

It may be assumed that 150 feet per minute is an ample self-cleansing velocity for ordinary sewers when running half-full or thereabouts, and 135 feet per minute is probably quite sufficient for a shallow flow, such as that discharged in dry weather, provided the sewage be sufficiently deep to float or submerge the solid matters contained in it.

The inclinations necessary to produce a velocity of 150 feet per minute in circular sewers of various sizes, flowing half-full, or full, and in egg-shaped sewers flowing two-thirds their vertical height, are shown in Table 2; also the population which such sewers, when running full, would be capable of serving at 67 gallons per head per hour above storm-overflows, and $8\frac{1}{2}$ gallons below storm-overflows.

Sewers should be constructed to flatter inclinations than the above, and these inclinations are only admissible where flushing power is provided.

TABLE II.

Size of Sewer.	Inclination to produce velocity of 150 feet pr. minute.	Population served by sewers above storm overflows.	Population served by sewers below storm-overflows.
Ft. In. Ft. In.			
0 6×0 6	1 in 174	165	1,297
0 9×0 9	" 261	370	2,919
1 0×1 0	" 349	658	5,189
1 3×1 3	" 436	1,028	8,107
1 6×1 6	" 524	1,481	11,675
2 3×1 6	" 661	2,080	16,390
2 6×1 8	" 734	2,567	20,235
2 9×1 10	" 808	3,106	24,485
3 0×2 0	" 882	3,697	29,140
3 3×2 2	" 955	4,340	34,200

In the preparation of the foregoing and following tables, the formulas used are those of Eytelwein, viz.:

$$V=5604\sqrt{R\,S}.$$

$$S=\frac{V^2}{R\,(5604)^2}.$$

Where V=velocity in feet per minute.
S=sine of inclination.
R=hydraulic radius.

To ascertain the gradients required for self-cleansing with the dry-weather flow, it is necessary to determine the amount of such flow as compared with the capacity of the sewers. According to the figures already given, the maximum quantity to be provided for in sewers above storm-overflows is $33\frac{1}{2}$ times, and in sewers below storm-overflows $4\frac{1}{4}$ times, the maximum dry-weather flow. The difference, however, between the dry-weather flow and the capacity of the sewers would often be considerably greater than this, as sewers are of necessity somewhat larger than necessary for the maximum flow, through certain portions of their length, especially on approaching dead ends. To allow the required margin, let it be assumed that the capacity of sewers above storm-overflows is 45 times, and below storm-overflows 5 times, the maximum dry-weather flow. Working upon these proportions, the inclinations required above storm-overflows in sewers of various sizes, to produce a velocity of 135 feet per minute with the dry-weather flow, are shown

by Table 3; also the depth of the dry-weather flow, the assumed population contributing to it, the velocity when running full, and the population which the sewers, when running full, would be capable of serving, at 67 gallons per head per hour.

Table 3.

Size of Sewer.	Inclination to produce velocity of 125 ft. per minute, with maximum dry-weather flow.	Depth of dry-weatherflow, or of flow equal to one forty-fifth the capacity of sewer.	Population contributing to dry weather flow.	Velocity when running full, in feet per minute.	Population served by sewer when running full at 67 gallons per head per hour.
Ft. Ins. Ft. Ins.		Inch.			
0 6 × 0 6	1 in 50	0.56	230	280	308
0 9 × 0 9	" 75	0.83	514	"	691
1 0 × 1 0	" 100	1.11	915	"	1,229
1 3 × 1 3	" 125	1.39	1,428	"	1,919
1 6 × 1 6	" 150	1.67	2,057	"	2,764
2 3 × 1 6	" 214	2.63	2,708	252	3,638
2 6 × 1 8	" 238	2.92	3,343	"	4,491
2 9 × 1 10	" 262	3.21	4,046	"	5,435
3 0 × 2 0	" 286	3.50	4,816	"	6,468
3 3 × 2 2	" 310	3.79	5,650	"	7,590

Table 4 gives particulars, similar to those in the preceding Table, with reference to sewers below storm-overflows, the maximum flow being taken at 8½ gallons per head per hour.

Table 4.

Size of Sewer.	Inclination to produce velocity of 135 ft. per minute, with maximum dry-weather flow.	Depth of dry-weather flow, or of flow equal to one-fifth the capacity of sewer.	Population contributing to dry-weather flow.	Velocity when running full in feet per minute.	Population served by sewer when running full at 8½ gallons per head per hour.
Ft. Ins. Ft. Ins.		Inch.			
0 6 × 0 6	1 in 145	1.76	1,213	165	1,427
0 9 × 0 9	" 217	2.64	2,729	"	3,211
1 0 × 1 0	" 289	3.52	4,852	"	5,708
1 3 × 1 3	" 361	4 40	7,581	"	8,919
1 6 × 1 6	" 434	5.28	10,917	"	12,843
2 3 × 1 6	" 525	8.79	15,577	161	18,326
2 6 × 1 8	" 583	9.77	19,231	"	22,625
2 9 × 1 10	" 642	10.75	23,270	"	27,377
3 0 × 2 0	" 700	11.72	27,693	"	32,580
3 3 × 2 2	" 758	12.70	32,502	"	38,237

The difference shown in Tables 3 and 4 between the population contributing to the dry-weather flow, and the population which the sewers are capable of serving, represents the margin allowed in determining the amount of the dry-weather flow, as compared with the maximum flow, as previously explained. Should the population contributing to the dry-weather flow be less than that stated, in which case the volume of sewage would also be less, an increased inclination would be required to give the self-cleansing velocity.

The size of sewer for inclinations other than those in the tables may easily be calculated from those given, the discharge being in proportion to the square

root of the sine of the inclination. The sine, however, for a given population and given inclination, may vary considerably, according to the local conditions affecting the volume of sewage per head to be disposed of.

With sewers on the combined system, the maximum amount of water to be dealt with, in proportion to the population, would probably be, in an average case, three times that provided for in the tables; and the population served by a sewer of a given size would consequently be proportionately less.

ON THE CONSUMPTION OF FUEL IN LOCOMOTIVES.*

By M. GEORGES MARIE, Engineer of the Paris and Lyons Railway.

From "The Engineer."

During the past twenty years a great advance has been made in regard to economy of fuel in steam engines. In marine engines remarkable results have followed from the general use of compound cylinders and surface condensers; for whereas their consumption was formerly from $3\frac{1}{2}$ lbs. to $4\frac{1}{2}$ lbs. per indicated horse-power per hour, it has now been reduced to about 2 lbs., and sometimes even less.† Equally good results are obtained with Corliss engines. This progress in economy of fuel has led to the endeavor to effect a corresponding reduction in locomotives. But, before the ordinary build of locomotives so long in vogue is abandoned, their exact consumption ought to be ascertained. Generally it is measured in pounds per mile; but that mode is not a convenient one for comparison, because it takes no account of gradients, weight of train, speed, and train resistance, all of which are so variable that the bare statement of consumption per mile is of scarcely any value. The only proper way of reckoning the consumption, so as to admit of comparison under different circumstances, is in pounds per horse-power per hour; and this is accordingly the new methods described in the present paper, as applied to locomotives under ordinary working conditions. There is a general impression that locomotives consume as much as from $4\frac{1}{2}$ lbs. to $5\frac{1}{2}$ lbs. of fuel per horse-power per hour. With a view to dispel this very prevalent error, the author can quote experiments made by him during the last few years, which show an average consumption in good locomotives of 3.35 lbs., when the horse-power is measured by the work done at the circumference of the driving wheels, and of 2.91 lbs. when it is measured by the indicator diagrams; the fuel being of good quality and the firing done with care. Comparing this with the marine engine consumption of 2 lbs. per indicated horse-power, it is seen that locomotives are much more economical than is usually supposed, considering that they work non-condensing while marine engines enjoy the great advantage of condensation. The author's first experiments on this subject, made in 1877 on the line between Rive-de-Gier and St. Etienne in the department of the Loire, gave a consumption of 2.90 lbs. to 3.24 lbs. per indicated horse-power per hour;* other experiments confirming this consumption were also made on a longer length between Alais and Langeac on the Nimes and Clermont line. These results, which were widely criticised, led M. Hirsch, Professor of Steam and Engineering at the Ecole des Ponts et Chaussées, to request that the experiments might be repeated in his presence. Fresh trials, which may be considered official, were accordingly made with him on 18th, 20th and 21st of July, 1882, on the Mont Cenis line between St. Jean de Maurienne and Modane, with the ordinary trains. The average consumption was again found to be 2.90 lbs. per indicated horse-power per hour. In these experiments neither indicator nor dynamometer of

* Read before Institution of Civil Engineers.

† See Paper by Mr. F. C. Marshall, Proceedings 881, p. 452.

* See "Revue des Chemins de fer," July 1881, p. 17.

any kind was used, such delicate instruments being liable to give rise to errors. Indicators especially occasion considerable errors through the oscillations of the piston-rod and spring, and in general give accurate results only from stationary engines working at slow speeds. The following are the particulars of the three days' trials, which it is hoped will successfully clear the locomotive from the imputation of wastefulness in consumption of fuel.

Choice of Line.—For experiments of this kind the writer generally chooses a steep rising gradient, because the work performed by the engine can then be easily and accurately calculated. It then consists of two portions: first, the work due to the train resistance on a level; and secondly, that due to gravity on the incline. On a steep rising gradient this latter portion becomes much the more important, while it can always be determined with accuracy, being the product of the total weight of train and engine, multiplied by the difference in level between the two ends of the incline; whereas the calculation of train resistance on a level is always subject to slight errors, arising from variations in the circumstances of wind and weather. Hence the steeper the incline up which the engine takes the train, the greater is the accuracy with which work done can be calculated. In this way the engine duty can practically be determined without the use of either indicator or dynamometer of any kind. The portion of line selected for the trials has the length of $27\frac{1}{3}$ miles between St. Jean de Maurienne and Modane stations on the Mont Cenis line; the gradients are 1 in 100 to 1 in 35, rising towards Modane, which is 1709ft. above the lower station; the average gradient is 1 in $53\frac{1}{2}$.

Choice of Train.—The train chosen was a passenger train starting from St. Jean de Maurienne at 12.21 noon, stopping only once on the way, at St. Michel, for three minutes, and reaching Modane at 1.25 P. M.; the average speed being accordingly 17.40 miles per hour. The engine, built from the designs of the writer's father, the late Ernest Marié, had eight wheels coupled, and its principal dimensions were as follows:

Cylinders	Diameter.....	$21\frac{1}{4}$ in.
	Stroke.......	26 in.
Wheels, diameter.........		4 ft. $1\frac{5}{8}$ in.
Heating surface		
	Fire-box.. 104.52	2149.70 sq. ft.
	Tubes.....2045.18	
Fire-grate area...........		22.39 sq. ft.
Boiler pressure...........		128 lbs. per sq. in.

The weight of the train, ascertained with the greatest care, was 163.58 tons, the particulars of which are given in the tabular summary appended; engine, tender and carriages were all weighed accurately on weighing machines.

Calculation of work done.—If calculated at the circumference of the driving wheels, not in the cylinders, the work done is exclusive of the engine friction, and is given by the following formula: Work done$=W\times l\times r+W\times h$. Here W $=$total weight of train, including engine and tender $=$ 163.58 tons $=$ 366,419 lbs.; $l=$ distance run$=$17.334 miles$=$91,536 ft.; $r=$coefficient of resistance $=\frac{1}{232.5}$ in the present case, or $9\frac{5}{8}$ lbs. per ton; $h=$height of train's ascent$=$1,709ft. The choice of the coefficient $\frac{1}{232.5}$ will be explained further on. Substituting the foregoing values—

$$\begin{aligned}\text{Work done} &= 366{,}400 \times \left(91{,}536\times\frac{1}{232.5}+1709\right)\\ &= 366{,}400 \times (394+1709)\\ &= 770{,}600{,}000 \text{ foot pounds.}\end{aligned}$$

Of this work the portion due to the resistance on a level amounts to only $\frac{394}{394+1709}$ or barely one-fifth, while gravity absorbs the remaining four-fifths. Hence an error of as much as 10 per cent. in the coefficient of resistance occasions only 2 per cent. error in the calculation of the work; while even 20 per cent. error in the coefficient causes only 4 per cent. error in the result. Although, therefore, the coefficient here taken of $\frac{1}{232.5}$ may be open to criticism, it is clear that it may be considerably modified without sensibly affecting the calculation of the work done. This constitutes the principle on which the author's trials have been based; whereby he has been enabled to arrive at an accurate deter-

mination of the work done, without the use of either indicator or dynamometer of any kind. The only objection to the method is that it applies only to moderate speeds, inasmuch as high speeds would be dangerous on the curves of a mountain line.

Consumption of fuel.—To ascertain correctly the consumption of fuel the author employed a different method from that ordinarily followed in locomotive trials. The general plan is, after lighting the fire and getting up steam, to note the pressure shown by the gauge, and the height of the water level, and to estimate the quantity of coal then on the grate. The trial is then made, and is so arranged as to end with the same pressure and water-level as at starting, and the coal remaining on the grate is again estimated. The correct consumption is arrived at by measuring the quantity consumed on the journey, adding what was on the grate at starting, and subtracting what remains at the end. Unfortunately it is impossible to determine correctly the quantity of burning fuel on the grate; and in consequence the calculated consumption almost always involves a serious error. This is one cause of the discrepancies met with in statements of fuel consumption. In the author's trials the above source of error has been completely avoided by the following mode of procedure. The engine tried had already made one journey that morning, so that it was in steam, with a pressure of 46 lbs. per square inch, before lighting the fire for the experimental trip. The water-level was 5.16in. above the mean line. The fire-grate was cleared of every particle of fuel from the previous journey. The tender was loaded with one ton, or 2,205 lbs., of Anzin patent fuel in bricks, and 119 lbs. of wood was served out for lighting the fire. The wood was included as fuel in reckoning the actual consumption, and was taken as equivalent to not more than 44 lbs. of coal; the total supply of coal would therefore be 2,249 lbs. Steam was quickly got up, and shortly afterwards the engine was coupled to the train in St. Jean de Maurienne station, and proceeded thence up the incline to modane. The trip was made with the engine working in the ordinary way, with 128 lbs. of steam, cut off at 19 per cent. of the stroke. Professor Hirsch, and M. Bazire, of the locomotive department, accompanied the author on the engine. The firing was so managed as to have no coal at all left on the grate on reaching Modane. The steam pressure was then found to be 20 lbs. per square inch, and the water-level 4.49in. below the mean; the datum level in the locomotives of the Lyons Railway being not the actual low-water line, but a mean level below which the water may fall without danger. The water-gauge was of course observed while the engine was on the level portion of the line in the station, the line running level through every station on this railway. The coal remaining in the tender weighed 1,133 lbs., which would show a consumption of $2,249-1,133=1,116$ lbs., if the boiler had been in exactly the same state after the trip as before; but no skill could succeed in securing the same steam pressure and the same water-level as on lighting the fire. A slight correction has therefore to be made in the coal consumption, to allow for the difference in quantity of heat contained in the boiler before and after the trip.

Correction for difference of heat in boiler.—Calculating first the quantity of heat contained in the boiler on lighting the fire, and secondly, the heat remaining in it after the trip, the difference converted into pounds of coal will be the correction to be made in the weighed consumption of 1,116 lbs., to give the true consumption. Firstly, at the time of lighting the fire, when the water-gauge stood at 5.16in. above datum, the quantity of water in the boiler would be 1,571 gallons, or 251 cubic feet, as ascertained from the dimensions given in the tabular summary appended. The temperature corresponding with the steam pressure of 46 lbs. is 293 deg. Fah. The weight of water, therefore, allowing for its expansion, would be 14 506 lbs.; and this, at the temperature of 293 deg. Fah., would contain 3,436,000 heat units, reckoning from the temperature of the air at the time, which was 59 deg. Fah. The metal of the boiler, weighing about 20 tons, would contain about 1,175,000 heat units. The heat in the steam may be neglected. Hence the total quantity of heat contained in the boiler at the time of lighting the fire, above the air tem-

perature of 50 deg. Fah., would be 4,611,-000 units. Secondly, the heat remaining in the boiler after the trip, estimated in the same manner, would amount to 3,143,000 units. The difference, or 1,468,-000 units, is therefore the additional heat expended during the trip. As the weight of dry steam generated per pound of coal consumed was found to be 8.08 lbs., and as each pound of steam at the pressure of 128 lbs. per square inch contains 1,169 heat units above this feed-water temperature of 59 deg. Fah., the boiler would produce, in practice, $8.08 \times 1,169 = 9,445$ heat units per pound of coal. The additional expenditure of 1,468,000 heat units during the trip is therefore equivalent to 155 lbs of coal, which, added to the weighed consumption, gives 1,271 lbs. as the true consumption of coal for the trip.

Consumption of fuel per effective horse-power per hour.—The work done, corresponding with the above consumption of 1,271 lbs. was 770,600,000 foot-pounds. Hence the coal consumption per horse-power per hour was

$$\frac{33,000 \times 60 \times 1,271}{770,600,000} = 327 \text{ lbs.},$$

the work being the effective work, *i. e.*, that measured at the circumference of the driving wheels. Throughout the foregoing calculation, the only coefficient open to dispute is that of the train resistance, which has been taken at $\frac{1}{232.5}$; but it has been seen that even a considerable percentage of error in this coefficient would involve no appreciable error in the final result of 3.27 lbs. consumption per effective horse-power per hour. To get at the consumption per indicated horse-power per hour, it is only necessary to deduct the proper allowance for the engine friction; which has been found, in careful experiments made by the writer's father, to absorb at least 12 per cent. of the indicated power, when the engine is in perfect working order. Hence the corresponding consumption per indicated horse-power per hour would be $3.27 \times \frac{100-12}{100} = 2.88$ lbs. as a maximum.

Consumption of water and production of dry steam.—The consumption of water on the trip, from the tender and from the boiler, was measured with the greatest care, allowing for expansion of the water in the boiler. It was found to amount to 11,290 lbs., or 8.88 lbs. per lb. of fuel. Deducting 9 per cent. for priming, the weight of dry steam produced would be 8.08 lbs. per lb. of fuel.

Nature of fuel—Samples carefully analyzed of the Anzin patent fuel, which was used in the trip, showed 6.9 per cent. of ash, and 1 per cent. of moisture. The heating power was found to be 14,-600 units per lb. It was ascertained by means of apparatus specially made for the purpose, similar to that used by Ebelman, Fabre, Silbermann and Berthelot, in their experiments on the heating power of fuel. It consists of a glass phial, within which a powdered sample of the fuel, placed in a crucible, is burnt in a current of oxygen; the phial is immersed in a measured quantity of water, and the rise of temperature in the water indicates the heat developed by the combustion of the sample. Cardiff coal was tried in the same way by the author, and gave the same heating power; a direct comparison can therefore be made between the experimental trip and any English trials with Cardiff coal. The Anzin patent fuel is in fact composed of 91 per cent. of slack, of the same quality as Cardiff coal, and 9 per cent. of coal pitch, the heating power of which has been found by the writer to be equal to that of ordinary coal.

Remarks.—During the experiment, the admission of steam to the cylinders was for 19 per cent. of the stroke, the steam in the waste spaces being included. The valve gear was tested by Professor Hirsch himself. The locomotive had not been repaired for a long time. It may be objected that the driver probably looked after the fire much more closely than usual, being stimulated by the presence of the engineers. This may be, but, on the other side, the following circumstances were unfavorable to economy of fuel: (1) During the firing up, the locomotive gave out some heat to the atmosphere as usual; this loss of heat was equivalent to about 29 lbs. of fuel, according to an experiment made for that special purpose. (2) In the last few minutes of the trial, the engine was run-

ning with a very low pressure, which was necessary in order to arrive at Modane without any fuel on the fire-grate ; hence the engine was working during these minutes in unfavorable circumstances.

Experiments made the 20*th and* 21*st July*, 1882.—The author, with Professor Hirsh, made two other experiments of the same kind as the first: on the 20th July, with patent fuel from the Grand Combe in the Gard coal basin, and on the 21st July, with patent fuel from La Chazotte in the Loire basin. The results were almost exactly the same as before. A tabular summary of the three experiments is appended in which all the figures may be seen at a glance. The experiments were all made with the same driver, the same engine, and the same kind of train. It will be noted that they were made in July, that is to say in the middle of summer. In winter the consumption of fuel is about 10 to 15 per cent higher, on account of the loss of heat to the atmosphere. The author considers that this loss of heat might be diminished if the clothing of the boiler were better—a point which assuredly is susceptible of improvement, especially for cold countries.

Conclusions.—The author has proved that with a good locomotive and a good driver the consumption of fuel and water is as follows :

Consumption of fuel per effective horse-power per hour....................3.27 lbs.
Consumption of fuel per indicated horse-power per hour...............2.88 lbs.
Ratio of consumption of water to consumption of fuel. 8.88
Ratio of dry steam produced to fuel consumed.........................8.08

Professor Hirsch attributes these satisfactory results to the following causes: (1) The total heating surface of the boiler is very large compared to the grate surface—96 to 1—so that the boiler absorbs the heat of the gases very completely; (2) the cylinders of the locomotive are very large—according to the late M. Marié's system—so that the grade of expansion is high; (3) the locomotive was very well looked after, which is an important point in economy of fuel. The author may also refer to some experiments made by M. Regray, chief engineer of the Eastern Railway of France; they were made with an indicator on a new system, giving diagrams at the highest speeds without the errors of the ordinary indicator. M. Regray, on this system, takes the diagrams at some distance away from the locomotive itself; the indicator is in a special van, with several dynamometers, speed indicators, &c. This van was shown at the Electric Exhibition in Paris, and obtained one of the highest prizes.

M. Regray made a few experiments on consumption of fuel in express engines hauling express trains; the result was 3.01 lbs. per indicated horse power as an average, and 2.48 lbs. as the minimum. This is a very satisfactory verification of the author's result, viz., 2.88 lbs. per indicated horse-power. It is important to notice that these very close results have been arrived at by two methods as different as they could possibly be. The fuel employed in M. Regray's experiments was not patent fuel, but ordinary small coal from Bascoup, in Belgium. These satisfactory results confirm what the author's father always maintained, namely, that locomotive engineers ought to use large heating surfaces and large cylinders; he always built his own locomotives by that rule.

The author has thus endeavored to prove that locomotives are not so imperfect as engineers generally believe, as regards economy of fuel. Assuredly the locomotive is a very simple form of engine; but simplicity is of great importance with the very high piston-speed of locomotives. That speed, however, is very favorable to economy in fuel—contrary to the opinion of some engineers—because it diminishes the leakage of steam and the condensation of steam during admission. A locomotive working with a very slow piston speed is not so economical as with a high speed. Express engines give better results than mountain engines, as is seen by M. Regray's experiments, where the consumption attained the very low figure of 2.48 lbs. per indicated horse-power under the best circumstances.

The author has no intention of implying that locomotives will not be improved—in fact, he proposes to indicate further on the probable directions of improvement; but before abandoning the ordinary system, he thought it would be interesting to make exact experiments,

TABULAR SUMMARY OF EXPERIMENTS.

Items of experiments.	Units.	18th July. Patent fuel Anzin.	20th July. Patent fuel Grand' Combe.	21st July. Patent fuel La Chazotte.
Total distance run by train.	foot	91,536	91,540	91,540
Ratio of resistance on level to weight of train.	ratio	$\frac{1}{232.5}$	$\frac{1}{232.5}$	$\frac{1}{232.5}$
Difference of level of the two stations	foot	1,709	1,709	1,709
Weight of engine and tender (not loaded)	lbs.	125,076	125,076	125,076
Weight of carriages and vans (not loaded)	"	204,800	225,285	176,212
Weight of the load on engine and tender	"	21,614	24,738	26,422
Weight of passengers and men	"	7,409	5,711	4,785
Weight of goods	"	4,575	4,264	3,149
Total weight of train	"	366,474	385,074	335,614
Before firing the boiler at St. Jean-de-Maurienne. Patent fuel and fagots loaded on tender	lbs.	2,249	2,251	2,249
Before firing the boiler at St. Jean-de-Maurienne. Pressure in boiler (above atmospheric pressure)	lbs. per sq. in.	46.28	21.36	18.23
Before firing the boiler at St. Jean-de-Maurienne. Height of water in boiler (above water-line)	inch	+5.16	+5.24	5.08
After arrival at Modane. Fuel remaining on tender	lbs.	1,133	966	1,158
After arrival at Modane. Pressure in boiler (above atmospheric pressure)	lbs. per sq. in.	19.65	21.36	7.83
After arrival at Modane. Height in water in boiler (above or under water-line)	inch	–4.49	+0.82	–4.73
After arrival at Modane. Depth of water withdrawn from tanks during the experiment	inch	19.38	27.30	17.38
Weight of metal in boiler	lbs.	44,100	44,100	44,100
Capacity of boiler, water being at water-line.	cubic foot	217.4	217.4	217.4
Diameter of cylindrical shell	foot	4.92	4.92	4.92
Total length of boiler	foot	22.31	22.31	22.31
Distance from water-line to top of boiler	foot	0.984	0.984	0.984
Horizontal surface of tanks in tender	square foot	73.59	73.59	73.59

giving the consumption of fuel per horse-power. Comparative tests with the various kinds of new locomotives ought to be made, and with the same accuracy. Unfortunately different drivers, working in the same circumstances and with the same kind of locomotive, show consumptions of fuel varying by from 10 to 20 per cent., according to their skill. This is a serious difficulty in making such comparisons between various systems of locomotive.

Comparison of practical results as to consumption with theoretical results.—The author will now compare the practical results in consumption of fuel with the theoretical results given by thermodynamics. This will give the measure of the improvement which remains to be made as regards the economy of fuel.

Efficiency of boiler.—We have seen that the boiler gives 8.08 lbs. of dry steam for 1 lb. of coal, at 128 lbs. per square inch pressure. Now, 1 lb. of water at 59 deg. Fah. requires 1169 units of heat to make 1 lb. of dry steam at 128 lbs. pressure. Thus, the boiler absorbs $8.08 \times 1169 = 9445$ units of heat for each pound of fuel, whose calorific power is 14,600 units, as stated above. The effi-

TABULAR SUMMARY OF EXPERIMENTS (*continued*).

Items of interest.	Units.	18th July. Patent fuel Anzin.	20th July. Patent fuel Grand' Combe.	21st July. Patent fuel La Chazotte.
Work of locomotive measured at circumference of driving wheels	foot-lbs.	770,600,000	810,100,000	705,900,000
Apparent consumption of fuel	lbs.	1,116	1,286	1,094
Before firing the boiler at St. Jean-de-Maurienne.				
Volume of water in boiler	cubic feet	251.34	252.04	250.98
Temperature of water in boiler	degs. Fah.	293°	261°	255°
Weight of water in boiler	lbs.	14,509	14,663	14,652
Units of heat in water	British units	3,436,000	2,985,000	2,901,000
Units of heat in metal	British units	1,175,000	1,012,000	988,000
Units of heat in boiler, total	British units	4,611,000	3,997,000	3,889,000
After arrival at Modane.				
Volume of water in boiler	cubic feet	182.40	223.41	180.64
Temperature of water in boiler	degs. Fah.	257°	261°	232°
Weight of water in boiler	lbs.	10,637	13,031	10,703
Units of heat in water	British units	2,135,000	2,652,000	1,885,000
Units of heat in metal	British units	1,008,000	1,024,000	885,000
Units of heat in boiler, total	British units	3,143,000	3,676,000	2,770,000
Loss in units of heat	British units	1,468,000	321,000	1,119,000
Corresponding weight of fuel	lbs.	155	33	123
True consumption of fuel	"	1,271	1,319	1,217
Consumption of fuel per effective H. P. per hour	"	3.27	3.22	3.40
Consumption of fuel per indicated H. P. per hour	"	2.88	2.84	2.99
Weight of water lost by tender	lbs.	7,420	10,449	6,650
Weight of water lost by boiler	"	3,872	1,632	3,949
Total consumption of water	"	11,290	12,081	10,599
Total consumption of water per lb. of fuel	"	8.88	9.15	8.68
Weight of dry steam per lb. of fuel	"	8.08	8.32	7.90
Ash in fuel	per cent.	6.90	9.70	9.60
Moisture in fuel	per cent.	1.00	1.30	1.10
Calorific power of fuel	British units	14,600	14,400	13,700

ciency of the boiler is, therefore, $\frac{9445}{14,600}=$ 0.65. That is to say, the boiler utilizes in practice 65 per cent. of the heat given out by the combustion of the fuel, and loses 100—65=35 per cent. This loss is due to the following causes: (1) Loss of heat contained in the gases escaping at the chimney; (2) loss of heat by conduction to the atmosphere; (3) loss of heat by the presence of some little air in excess of that needed for combustion; (4) loss of heat by the escape of a small portion of carbonic oxide not burned into carbonic acid; (5) several minor causes. It is remarkable that the total loss of heat should be only 35 per cent. with so many causes of waste. One of the best improvements that can be applied to locomotives is the heating of the feed water with the exhaust steam. MM. Kirchweger, Mazza, Chiazzari, and Körting have designed several apparatus for that purpose. None of them have been a practical success, but the author hopes the want will be supplied before long.

Efficiency of the locomotive-boiler and engine together.—The quantity of work which a steam-engine can theoreti-

cally give out for one unit of heat* depends—(1) On the temperature corresponding to the boiler pressure; (2) on the temperature of the condenser. The maximum of work in foot pounds given by one unit of heat is $772 \times \frac{T^1 - T^2}{T^1 + 461.2}$. Here 772 foot-pounds is the mechanical equivalent of heat; T^1 is the temperature Fah. corresponding to the boiler pressure; T^2 is the temperature Fah. of the condenser, which in steam engines without condensation, is the temperature of boiling water; 461.2 is the number of degrees below Fah. zero of the absolute zero of thermo-dynamics. Applied to the present case of the locomotive, the formula gives $772 \times \frac{356-212}{356+461.2} = 136$. That is to say, under such conditions, a theoretical steam engine would give 136 foot-pounds of work for one unit of heat. In practice we have seen that the locomotive gives 1 indicated horse-power per hour, or 1,980,000 foot-pounds for 2.88 lbs. of fuel, giving $2.88 \times 14{,}600 = 42{,}450$ units of heat. Thus the locomotive—boiler and engine—gives practically $\frac{1{,}980{,}000}{42{,}450} = 46.6$ foot-pounds for one unit of heat. The efficiency of the locomotive—boiler and engine—is, therefore, $\frac{46.6}{136} = 0.35$.

Efficiency of engine alone.—The efficiency of the engine alone is clearly equal to $\frac{0.35}{0.65} = 0.54$. That is to say, the mechanism of the locomotive, receiving steam and giving out work, gives 54 per cent of the work which a theoretically perfect engine should give in the same circumstances. The loss of work is $100 - 54 = 46$ per cent. This is due to the following causes: (1) Loss of work from the expansion of steam in the cylinders not being quite complete. (2) Throttling the steam, on entering or leaving the cylinders. (3) Back pressure of the steam during the return stroke. (4) Imperfection of the valve motion. (5) Condensation of steam during admission. (6) Leakages of steam, and several minor causes. Such are the many causes of the loss of work in the engine proper. The resulting efficiency of 54 per cent. is assuredly not so good as the efficiency of the boiler, which is 65 per cent.; still a loss of 46 per cent. is not very remarkable where so many causes contribute to produce it.

Comparison with a Corliss engine.—The author made a similar investigation with reference to a boiler and engine on the Corliss system, with condensation. The power was measured by an indicator; the consumption of fuel was also measured, and the results were as follows: Pressure in boiler, 5.5 atmospheres; temperature, 313 deg. F.; pressure in condenser, 0.9 atmospheres; temperature, 111 deg. F.; consumption of fuel per 1 H. P., 2.01 lbs. per hour; ratio of dry steam evaporated to fuel consumed, 9.5; calorific power of fuel, 14,500. The efficiency of the boiler and of the engine, compared with the theoretical results of thermo-dynamics, has been calculated, with the following results: Efficiency of boiler, 64 per cent.; efficiency of mechanism done, 53 per cent. These results are almost exactly the same as with locomotives, which give, as we have seen: Efficiency of boiler, 65 per cent.; efficiency of mechanism, 54 per cent. That is to say, the locomotive, compared with a theoretically perfect locomotive, is quite as good as a Corliss condensing engine compared with a theoretically perfect engine working as a Corliss engine. The author concludes that the locomotive is not so bad as engineers generally believe as regards economy of fuel. The general conclusion is that locomotives are not capable of much improvement as regards the economy of fuel, unless the pressure in the boiler can be increased. When the improvements in material and construction will allow the use of higher pressures, then a notable economy will be easily obtained in proportion to the increase in the value of the expression $\frac{T_1 - T_2}{T_1 + 461.2}$. But in that case the author considers it will be necessary to employ compound cylinders, or more complicated valve gear in order to obtain the best utilization and highest expansion of the steam. In concluding this paper, he wishes to add his tribute of admiration to those English engineers who have

* See "A Manual of the Steam Engine and other Prime Movers," by W. J. Macquorn Rankine. London, 1876, p. 343.

done so much for the existence and improvement of railways. To George Stephenson we owe the locomotive in its present form, the excellence of which, as regards the economy of fuel, is still worthy of admiration, while another eminent English engineer, Mr. Webb, is now carrying out a remarkable series of experiments, with the view of bringing it to its greatest possible degree of perfection. Having received from Mr. Webb himself details of his compound locomotive, which he has also had the pleasure of seeing at Crewe, the author is led to add here the few observations that have occurred to him in regard to this new kind of locomotive. If the boiler pressure be not higher than in ordinary locomotives, the author thinks the economy of fuel cannot be greater in the compound engine than in the best ordinary locomotives. With the ordinary boiler pressure of 9 atm., or 135 lbs. per square inch, the ordinary valve gear gives expansion enough, provided the cylinders be large enough, which is not always the case. The compound system lessens the injurious effect of the clearance spaces, and also diminishes the condensation of the steam during admission; but these two advantages are neutralized by the disadvantage of the steam being throttled in its passage from the first cylinder to the second, especially at high speeds. In other words, the consumption of fuel in a compound engine could not, in the author's opinion, be much lower than that given in the present paper, the boiler pressure being the same. This point would be readily settled by a few experiments on the consumption of fuel per horse-power per hour in the compound locomotive, including lighting up. The particular locomotives of ordinary class, with which the compound engine has been compared by Mr. Webb, appear to the author to be somewhat too heavily loaded for the best economy, their cylinders being smaller than those of the express locomotives on the Paris and Lyons Railway, which have cylinders of 19.7 in. diameter, and 24.4 in. stroke, with 6 ft. 6 in. driving-wheels. Fuel being very expensive on this line, the author's father always made his engines heavy, but very economical; and these express engines, which were designed by him and built at the works of the Paris and Lyons Railway, and of Messrs. Sharpe, Stewart & Co., are some of the most economical locomotives there are. The author has, indeed, made experiments, in which—on the same kind of line, and at the same speed, and with the same total weight of train—the consumption of fuel was almost exactly the same as in the latest experiments with the compound locomotive; but he cannot look upon such a comparison as of great value, because it is impossible to estimate precisely the difference of circumstances in the two cases. The further experiments he has suggested with the compound engine seem, therefore, to be needed for a fair comparison. In his own experiments the author has found 9 atm., or 135 lbs. per square inch, to be the maximum boiler pressure for obtaining good expansion with ordinary valve gear and with cylinders of ordinary size. With higher pressures, either better valve gear must be employed, or the compound system; and the latter is considered decidedly preferable by the author, who has shown that great economy of fuel can be obtained with a higher boiler pressure. In the compound locomotive the boiler is very light and very strong; and the author looks forward to the pressure of steam being yet further increased during the next few years, without making the engine too heavy for the rails. It will then be a necessity to adopt the compound system for obtaining good expansion; and the compound locomotive, without being too heavy, will then unquestionably be much more economical than ordinary engines could be, and will be well adapted for high speeds. Goods engines of the ordinary kind are not so economical in consumption per horse-power per hour as express engines; and the author anticipates, therefore, even better results from the compound system in goods engines than have been obtained with express locomotives. The compound system with yet higher boiler pressure, will thus, in his opinion, turn out to be the greatest improvement in locomotives since the time of Stephenson.

A NEW first-class Thornycroft torpedo boat, for the German Government, made the passage to Kiel, from London in fifty-two hours.

STORAGE BATTERIES.

From "Nature."

The importance and desirability of an efficient and economical storage battery have been very widely recognized, but it is at the present time pretty generally felt that no existing form of storage battery is perfect, and that they are on the whole extravagant and wasteful to an extent sufficient to more than compensate for their undeniable convenience. It is perfectly certain that their employment has not become at all general, and that they have failed to realize the somewhat sanguine hopes of their early promoters.

It seems worth while to examine into the causes of this partial failure, and to inquire how far the evil opinion held by many practical men concerning our present method of storing electrical energy is justifiable.

One of the main objections is that storage involves a loss of some 50 per cent. of the whole. Now all methods of storing and transmitting energy involve some loss. To say that any particular method involves a loss of 50 or even 90 per cent. is not to condemn it utterly. There are many cases when the convenience of storage outweighs the evil of waste altogether; three principal ones may be specified.

(1) When the power of the source would be otherwise so completely wasted that every fraction of it stored is clear gain. This is the case of much terrestrial water power. The energy of the tides or of Niagara is enormous, and wholly wasted so far as human activity is concerned; if 50 or even 10 per cent. could be stored in such a way as to be conveniently available, it would be of considerable value, and any arrangement capable of effecting this storage could only with injustice be stigmatized as wasteful. The solar energy of the Carboniferous epoch has most of it been wasted; but a small fraction—probably not a millionth per cent.—has been saved and stored in the Coal-measures. It is possible to abuse the coal for not having stored more, but we find it a useful modicum nevertheless.

(2) A second case when the advantage of storage over-balances the loss is when regularity and continuity of supply is needed, and when the source is irregular and fitful. Wind and wave power illustrate this kind of source; it is manifest that wind power has not been so largely used as it would have been, had it been steady and dependable. A practicable method of storing up its energy and giving it out as wanted would gradually cause it to be very largely employed. This case is also illustrated faintly by a gas-engine or jerky motor of any kind, and the regularity and dependableness of a storage cistern may very well make it desirable to put up with some waste provided it be not excessive. Mechanical devices for approximating to regularity, such as the use of slack driving belts, undoubtedly give rise to a waste of power, and so does any form of regulator. But in the utilization of artificial forms of power like this, questions of economy become almost pre-eminent; and wastefulness is here a most serious objection, and, it may be, prohibitive defect. At the same time, if the engine is liable to stop, or if it is not always working, some mode of storing energy may be absolutely necessary, whether wasteful or not.

(3) Another case, and to some extent the converse of the last, is when the available source is weak, though continuous, while the power is only needed for a short time, but during that time is required to be great. This is exemplified in the operation of pile-driving, where energy is stored in the slowly-raised weight to be suddenly expended on the head of the pile, also in the operation of drawing a bow; or again, when a small waterfall or steam-engine, running continuously, is to be utilized for lighting during five or six hours each day; the obviously right plan in such circumstances as these is to store the energy during the hours it is not wanted, and thus virtually to double or treble the power of the source while it is actually in use. Unless, however, the loss occasioned by storage were reasonably small,

there would be but small gain in attempting the process in this third case.

It is plainly advantageous to devise a method of storing that shall give out the greater part of what is put in; but we see by these examples that a reasonable loss may be more than compensated by convenience, regularity, availability and dependableness. Again, when energy has to be transmitted over great distances, it is in practice difficult or impossible to make the expenditure of energy at one end depend upon and be regulated by its consumption at the other; and so, without some system of storage, great waste will ensue during intervals of small consumption. Looking to the immense development which the transmission of energy may be expected to undergo in the course of the next few decades, a convenient and manageable method of receiving large quantities of transmitted energy, and of holding it in readiness until wanted, must be of prime importance.

It was in view of such applications as these that the invention of the storage by Faure was hailed with enthusiasm by the highest scientific authority in Great Britain; while the public, jumping to the conclusion that a thing for which so many uses could be instantly found must needs be a profitable investment, hastened to provide money, not for commencing careful experiments and perfecting the arrangement, which would have been wise, but for manufacturing tons of apparatus in its first crude, immature, and untried form. Some day it may perhaps be recognized that because it can be shown that a thing will be extremely useful when perfect it does not follow that it has already attained that perfection, that indeed probabilities based on historical developments are enormously against such abnormal and instantaneous maturity, and that the careful nursing and rearing necessary to healthy maturity are better given in the seclusion of laboratory and study than in the excited and heated atmosphere of the Stock Exchange. It is doubtless recognized already that all preliminary operations are better conducted on a scale smaller than the wholesale manufacturing one. In developing a new industry there are scientific difficulties to be overcome, and there are manufacturing difficulties. By scientific difficulties we mean such as the determination of weak points, the best ways of strengthening them, and generally the discovery of theoretically the best modes of effecting the object in view; manufacturing difficulties begin with questions of expediency and economy—how most cheaply and satisfactorily to carry out the indications of theory, to obtain this or that material—and include the organization of a system of manufacture, of division of labor, of machine tools, which shall enable the work to be done with economy, security and despatch. Overhaste in the preliminary stages causes both these sets of difficulties to be tackled together, and so throws a grievous burden on both adviser and manager. All these untoward conditions have storage batteries experienced; and to say they have not fulfilled the hopes of their early promoters is no more than to say that those hopes were untimely and unreasonable, The period of maturity has been undoubtedly delayed by injudicious treatment, but its ultimate attainment seems to us inevitable; and it is at present a matter of opinion how nearly it has already been reached—certainly great steps towards it have been made. Let us inquire what some of the difficulties encountered have been, and it will be seen that, formidable as some of them are, they belong essentially to an infantile stage, and are not suggestive of constitutional debility.

The first form of manufacture consisted in rolling up sheets of lead and composition, with trousering to keep them separate. The difficulties found were that the coatings would not adhere, but became detached in large flakes; that the trousering got corroded through and permitted short circuiting; and that free circulation of fluid being impossible, the acid became exhausted in some places and concentrated at others, and thus every sort of irregularity began. Now regularity or uniformity is of the most vital and fundamental importance in any form of battery. If any part of a plate is inactive, that part is better away; if any plate in a cell is inactive, it is better away; and if any cells of a battery are inactive, they are infinitely better away. The rolling or coiling up of the sheets being found awkward in practice

and liable to detach the coatings, flat plates came to be used, then perforated plates, and then cast grids; these last having such large hole space that they held enough composition, and held it securely enough, to enable the trousering or intermediate porous material to be dispensed with. This was an evident step in advance: free circulation of the liquid became possible, and could be assisted by stirring; there was nothing to corrode except the plates themselves, and the composition, being in the cells or holes of the grid, might be reasonably expected to adhere. So far expectation was not altogether belied. The adhesion was not perfect, it was true, and pieces of composition sometimes fell out of the holes, especially if too powerful currents were passed through the cell, but still it was much better than it had been; and if the plates were well filled, properly formed, and fairly treated, the composition adhered extremely well and securely. The circulation of the liquid was not automatically perfect either, but mechanical agitation could be readily applied; without it the acid near the bottom of the cells tended to become more concentrated than that near the top, not by reason of gravitation undoing diffusion, which is impossible, but because during each charging fresh acid is formed, and in great part falls to the bottom in visible streams. Another great advantage was that some amount of inspection of the plates became possible, and experience as to the actual behavior and appearance of the plates, began to be accumulated. And painfully varied that experience was. Every variety of extraordinary behavior which could be suggested as probable, and a good many which no one could possibly have imagined beforehand, made their appearance. The hundreds of tons of batteries made at this period doubtless enabled these unpleasant experiences to be more rapidly acquired than would have been done on a small scale, but it was a costly series of experiments. However, the experiments were made, the public involuntarily assisted in the acquisition of experience, and, caring less for knowledge than for marketable commodities, they expressed dissatisfaction at the result. Many of these incipient difficulties are now overcome by the manufacturers, but the great dislike of the public to involuntary experiments, and the shock which their confidence underwent on being unexpectedly called upon to participate in research, have not yet altogether abated.

The main difficulty now experienced was how to keep the plates from touching. They might be put in wooden frames, or elastic bands might be stretched round each of them, and if they would only keep flat it was impossible they should touch unless the composition should drop out of the holes. Sometimes the composition did drop out of a hole, and bridge across the interval between two plates, but the more common and more fatal experience was that the plates would not keep straight. In a few months the positives were found to swell, and as they swelled to buckle—to buckle and twist into every variety of form, so that elastic bands, wooden frames, and every other contrivance failed altogether to prevent short-circuiting. The cause of the buckling is, of course, irregular and one-sided swelling, and the cause of the swelling is apparently the gradual peroxidation and sulphating of the material of the bars of the lead grid, which occupy less room as metallic lead than as oxide or salt. As the bars swell, they press on the inclosed composition, occasionally driving it out, but more frequently, and with properly made and treated plates universally, distending themselves and stretching the whole medial portion of the plate. The edge or frame of the grid is stronger than the middle bars, and is not so easily stretched; in a good and uniformly worked plate it does stretch, and an old positive plate is some quarter of an inch bigger every way that a new one, but if one face of the plate is a trifle more active than the other, it is very plain that the most active side will tend to become convex; and buckling once begun very easily goes on. To cure it two opposite plans have been tried: one is to leave the plates as free and unconstrained as possible, hanging free, it may be, from two points, thin, and with crinkled or crimped margins to allow for expansion; the other is to make them thick and strong, with plentiful ribs for stiffness, and besides to clamp them up one to another as tightly as may be, and thus in mechanical ways to resist buckling and distortion. I do not know that any one

could say for certain beforehand which of these two plans would be likely to answer best, but practice is beginning to reply in favor of the latter, and well braced plates of fair thickness show no unmanageable tendency to buckle. It must be remembered that no material can buckle with a force greater than that necessary to restore it to flatness, and this force in the case of lead is very moderate. Hence it may be fairly hoped to overcome and restrain all exuberances by suitable clamps and guides arranged so as to permit flat and even growth, but to check all lateral warpings and excrescences.

Uniformity of action is still essential, especially if all the plates in a cell are clamped together. Plates mechanically treated alike ought to be electrically so treated also, and it is impossible to keep a set of plates working satisfactorily together unless the contact of each is thoroughly and equally good, so that each may receive its fair share of current. Defects of contact have been a fruitful source of breakdown and irregularity. Clamps and screws of every variety have been tried, but the insidious corroding action of nascent oxygen exerted through the film of acid which by spray and creeping forms and concentrates on the lugs—this corroding action crawls between the clamped surfaces, gradually destroys all perfect contact, and something produces almost complete insulation. Contacts on the negative plates give but little trouble; contacts on the positives have taxed a great amount of patience. Lead contacts "burned," *i. e.*, melted, not soldered on, are evidently less liable to corrosion than brass or copper fittings, or than any form of clamp, but they are apt to be somewhat clumsy if of sufficient conductivity, and moreover they are awkward to undo again, and somewhat troublesome to do. However they have proved themselves so decidedly the best that now no other contacts will be used, and their re-introduction has been followed by a marked improvement in the behavior of the cells. So long as contact with one plate was better than with another, a thing quite possible to happen without any difference being perceptible to the eye, so long was it possible for one or two plates to remain almost wholly inactive while another one or two received far more than their share of current, and became distended, warped, overcharged and ultimately crumbled away. If one or two plates in a cell are black, and giving off torrents of gas, while the rest are brown and idle-looking, it is pretty fair evidence of irregular and insufficient contact, or else of some great discrepancy in the age or make of the plates. This point also is one that was not attended to in the early stages of manufacture; plates were made for stock, and cells were made up with plates of all ages selected at random from the store. Directly uniformity is perceived to be essential, this is recognized as obviously bad. Plates intended to work together should be of the same age and make, and inasmuch as keeping does not improve them, the best plan is not to make for stock, but to keep material ready, and then quickly make up as wanted. Plates in work deteriorate slowly, but they are wearing out in the fulfillment of their proper function; plates in idleness deteriorate as quickly, and they are rusting out in fulfillment of no function at all. Worn-out plates, however, are by no means valueless. Lead material has a well-recognized price, and if attention were given to the subject, it is probable that decrepit and useless plates might be made to yield a very large percentage, if not the whole, of their original lead. For it must be remembered that plates deteriorate not by waste but by accretion: an old plate contains as much lead as a new one, but it contains it with the addition of oxygen and sulphion; no longer a tenacious coherent frame, but a crumbling mass of incoherent powder.

The age of plates is a point of vital interest, though but little is known as to the possibilities in this direction at present. A year may be regarded as a fair average age at the present time; but this is a low rather than a high estimate. Thick plates are found to last far longer than thin, which is only natural when it is remembered that the wearing out is due to corrosion, that corrosion proceeds mainly from the surface inwards, and that the internal portions of a thick plate are to a great extent protected by the mass of superincumbent material. If it can be shown, as we understand it can, (1) that the cost of materials is far more

than the cost of manufacture; (2) that the worn-out material has a market value not incomparably less than the original; and (3) that the frequency with which plates have to be renewed is not such as to cause much inconvenience; then we hold that the first stage of the durability difficulty has been overcome. Much more may be hoped for in this direction as experience increases, and it is not extravagant to hope that a well-ribbed, properly-clamped, and fairly-treated thick plate may last as long as five years before it becomes disintegrated.

It is evident, however, that in a region where pure experiment is pre-eminent, and where the units of time are months and years, instead of hours and days, the accumulation of experience is a slow and tedious process. It is no use making statements involving periods of five years when no one has had the present improved form in use for so much as six months. Nevertheless it is possible to see that the present cells are better than their predecessors; and as their predecessors have lasted in good condition for a year and more, it is not presumptuous to indulge in well-founded hopes. Many of the difficulties connected with the early forms of battery were aggravated by Utopian notions concerning internal resistance and compactness. The internal resistance of a cell was so beautifully small, that the manufacturers were tempted to diminish it still further by putting the plates far too close together. An eighth or tenth of an inch interval is well enough if the plates had been hard rigid slabs of perfect flatness; but it was madness to pack flexible lead plates full of composition certain to swell and liable to drop out so near together as this. Security and dependableness were sacrificed to a natural desire for sudden and Utopian perfection. We may hope that these lessons have been profited by, and that the manufacturers perceive that confidence and security are the first conditions of success, and that minutiæ as to the number of noughts before the significant figures in the specification of resistance begin, though those also are of importance in their turn, are yet of quite secondary consideration. Moreover, this packing of the plates so closely did not really do much to secure the result desired; the greater part of the resistance of half run-down cells is not in the liquid between the plates, but in the surface or scum separating each plate, and especially each negative plate, from the liquid, and hence putting the plates a safe distance, say a quarter or one-third of an inch apart, exerts an effect on the total resistance which is certainly far more than compensated by the ready opportunity thus afforded for access by both sight and touch. The old opaque boxes chock full of plates, with slight india-rubber bands between them, were started and left to Providence. No one could see what went on, nor could one readily get at anything to rectify what was wrong. In the present glass boxes properly arranged on accessible shelves with only plugs or studs between the plates, clear vision through the cell in any direction is easy, and accidental obstruction not only very seldom occurs but if it does it can without difficulty be seen and removed. But it must be granted that these boxes are less compact than their predecessors, and for some purposes, such as locomotion, compactness is of the first importance. Most true, for some purposes. It is not to be supposed that one type of cell will answer every possible demand. A dynamo to be highly efficient must have a large and massive field magnet, but in some places bulk and weight are fatal objections, and in these places smaller and more compact dynamos may be more suitable: something, however, must be given up to secure the required lightness and compactness, some sort of compromise must be effected. Just so with cells: we can point out what is theoretically the best form, and this form may, for large stationary electric light or power installation, be actually the most suitable; but we may also see that for boats, for tramcars, and for fish torpedoes, some very different and far more compact form may be quite essential.

Efficiency, durability, economy, compactness: it may not be possible to attain all these at once—if it were, there would be small room for discussion—but sometimes one and sometimes another will be the pressing necessity, and manufacturers of storage batteries, like manufacturers of dynamos, must be prepared with forms suited to various needs.

We have spoken mainly of difficulties

connected with the positive plates, and have said nothing concerning the negatives. It is not that these are not susceptible of improvement, but their faults have been of a less imperious and obtrusive nature. They are not perfect, but they do fairly well, and there has been little need to worry much about them, until the extraordinary behavior of positives had been taken in hand and checked. The time is coming to attend to these also. They fail not from exuberance, but from inertness. As they grow old, they do not swell, and warp, and burst, and crumble, like the positives, but they grow quietly hoary, and serenely decay. The composition in a worn-out negative consists of white sulphate through and through, but the frame remains intact, and it consequently never falls to pieces, nor does it swell. Impurities in the acid used tell upon a negative plate—nitric acid is fatal. Acid much too weak or very much too strong is also deleterious, and idleness is bad. The difficulties connected with negatives mostly depend on their aggravating property of always requiring a quite opposite treatment to positives. The less a positive is formed and overcharged the better. A negative delights in complete formation and frequent overcharge. In recognition of this it is now customary to form them separately, and to give the negative a thorough dose of hydrogen without commencing the corrosion of the positive by an overdose of oxygen. When the discharge from a cell begins to flag, it is the resisting scum of sulphate that has formed over the negative plate which is responsible for the flagging. The true E.M.F. of a cell is wonderfully constant throughout the whole discharge; but the internal resistance is all the time increasing, at first very slowly, ultimately, towards the end, with a rush. One such run-down cell in the midst of a lot of others, therefore obstructs the current terribly. If only a series of cells could with certainty be made to work together uniformly, if a series could behave as well as some of the cells in it, no one would have cause to complain.

Through the whole history of the manufacture, from the very beginning, a few cells here and there have always exhibited astonishing efficiency; the aim of manufacturers may be said to be to bring all cells up to the level of a few. Much progress in this direction has been made, and it may be very fairly expected that, as uniformity is gradually attained, a series of cells subjected to the same treatment may behave in the same manner. Whenever this is certainly accomplished, there will have been reached a high stage of efficiency, beyond which further progress need be only in the improvement of comparably insignificant minutiæ.

The subject of the electrical storage of energy is really one of national importance; it is comparatively a small matter whether this or that form of storage, or this or that company of manufacturers, succeeds in bringing out the permanent form. It sometimes unfortunately happens that enterprising pioneers only clear the way, and retire just in time for other men to come in and reap the fruits of their labors. So much capital and so much labor have been already expended in the effort to bring storage batteries to perfection, so great progress has been made, and so apparently small are the steps which yet remain to be accomplished, that we may surely fairly hope that some of the original believers in their great, and as it seems to us inevitable, future may yet live to see their faith justified and their patience rewarded, and may even taste some of that so-called "substantial" reward without the hope of which great commercial enterprises would never be undertaken, and modern civilization would have scarcely yet begun.

THE following is from a German patent, No. 20,939, for a method for the manufacture of artificial gutta-percha: About 50 kilos. of powdered gum copal, and from 7½ to 15 kilos. of flowers of sulphur are under continual agitation heated in a boiler with double the quantity of turpentine or with from 55 to 62 liters of petroleum to a temperature of 126 to 150 deg. C. till completely dissolved. The mixture is then allowed to cool down to about 38 deg. C., when a solution of 3 kilos. of caseine is added, the latter being dissolved in weak ammonia with the addition of a small quantity of alcohol and wood spirit. The mixture is now heated for a second time to the same temperature until it assumes the consistency of a thin fluid. It is then boiled with a solution containing from 15 to 25 per cent. of tannic acid —galls or catechu—to which ½ kilo. of ammonia has been added. After having been boiled for several hours the mass is allowed to cool, washed with cold water, and kneaded out in hot water. After this treatment it is rolled out and dried.

NOTES ON THE CONSTRUCTION AND EQUIPMENT OF NARROW-GAUGE RAILWAYS.

By A. L. REED, Chief Engineer P. H. & N. W. R. R. Port Huron.

Transactions of the Michigan Association of Surveyors and Civil Engineers.

When asked by the committee to prepare a paper on narrow-gauge railways I consented; but, on looking over the subject, I find so little to be said, except as to cost, that will not apply equally well to any railway, that I will simply note a few points on their construction and equipment in general, and then give you, somewhat in detail, the various items of cost particularly applicable to narrow-gauge roads, hoping they may be at least interesting to the members of the association, though I do not think they will be particularly instructive to those whose experience is largely in railroad work.

Location.—The question of location I need not allude to, except to refer you to the able paper on the subject read by Mr. Hodgman at your last meeting. His treatment applies as well to roads of one gauge as another. I will say, however, that curves and grades on narrow-gauge roads are just as objectionable as on any road; although sharper curves may be used, they should be avoided as much as possible.

Supposing our location to be completed, and grades established, we are ready to proceed with construction work; we will also suppose that the contract is drawn in proper form and the work let, subject to the proper specifications, as we are dealing more directly with the work of the engineer and the contractor.

Clearing and Grubbing.—The first work to be done is the clearing of the right of way and grubbing for the road bed; clearing should be done the full width of the right of way, whatever that may be, and all the logs, brush, and perishable matter be piled and burned, so as to be out of the way of the workmen as well as the contractor; as instances have been known where contractors have been tempted at least to use the logs, stumps, etc., lying along the right of way, for making the road-bed, which is not desirable except in special cases. The engineer should furnish the contractor, for use in clearing, notes of stations between which grubbing should be done, and width of grubbing, so that he may do no useless work and may do grubbing in connection with clearing, as a standing tree is much easier to grub out than a stump. All stumps and grubs should be taken out where the sub-grade line is within two feet of the surface, also on all cuts. Where the fill exceeds two feet low chopping will suffice, and in fills of four or more feet, stumps of ordinary height are not very objectionable and may be left standing, except where they are very large and decayed, when they should be removed.

Cross-Sectioning.—Clearing and grubbing completed, the engineer is ready to do his cross-section work, which consists in putting in stakes every 100 feet, or oftener if the surface of the ground is uneven, which stakes are set one in the center and one at the edge of each slope. Each stake should be plainly marked on one side with the number of the station at which it stands, and on the other with the cut or fill to sub-grade at the point where it stands. They should be set uniformly, the center stakes exactly on the center line, with the station number facing the backward direction of the line, and the slope or side stakes set at right angles to the line even with the center stakes, with the cut or fill facing the line. On uneven ground, plus or partial stations should be put in in the same manner as the regular stations, and the full station number should be put on each plus stake; thus a cross-section midway between stations 79 and 80 should be marked not simply +50 but 79+50. A little care in this direction will save a great deal of annoyance and time in subsequent work when stakes are knocked down by careless workmen and have to be replaced, possibly when the notes are not at hand. At every point where the grade and surface lines cross, there should be set a *grade stake* marked 0.0 or grade; this should be done not only

at the center but on each slope, and the plus station at which each occurs carefully noted.

Each cross-section should be carefully recorded in a cross-section book: the usual form being to place the center cut or fill in a central column, and left and right slopes in a column at left and right of the center in the form of fractions, with the cut or fill as the numerator, and the distance out from the center line as the denominator, with their respective signs, plus for cut and minus for fill, thus:

$$\begin{array}{ccc} \text{L.} & \text{C.} & \text{R.} \\ \dfrac{-2.0}{9.0} & +3.5 & \dfrac{+3.6}{13.4} \end{array}$$

showing a cut of 3.5 at the center, a cut of 3.6, and a distance out of 13.4 on the right and a fill of 2.0 with a distance out of 9.0 on the left. These distances apply to a road-bed of 12 feet on fills and 16 in cuttings with a slope of $1\frac{1}{2}$ to 1.

Experience has proved that there is no economy in building narrow road-beds. We commenced on the Port Huron and North-western Railway by making fills 8 feet at sub-grade and cuts 12 feet; then we widened banks to 9 feet; on our next work we made banks 10 feet and cuts 14, and now build banks 12 feet and cuttings 16 feet, which are none too wide, and are found to be more economical in the end.

As I believe the papers which are read from time to time before this association are intended to be of practical use to the members, rather than finished literary or scientific productions, let me give what I consider the best method of doing cross-section work. I have noticed that beginners almost universally use the cumbrous method of figuring out each station by itself from the height of instrument and grade height, a tedious as well as unnecessary work. First, set your level firmly, and in such a position as to command a good view of your work; bring it to a level, and take from the nearest bench mark a reading, which add to your bench height to give you the height of instrument. Now, from your cross-section book, note the grade of the station at which you propose to commence your work. The difference between your instrument height and grade height will be the reading of your rod at that station held at grade, and the difference between it and the actual reading at the point will be the cut or fill at that point.

To illustrate. Your bench-height is 80.10; your rod on bench mark reads 5.08, making height of instrument 85.18; your grade height at station 79 is 82.00; so your rod held at grade at station 79 should read 3.18. But suppose it actually reads 5.30; then your fill is 2.12; if it reads less than 3.18 you have a cut. If you are working on a level grade, all your grade readings will be the same, and you have no trouble; but if, for example, you are working on a down-grade of 26.4 feet per mile, add to your rod 0.5 for each station, which would give you 3.68 at station 80, and the difference between that and the actual reading will give you the cut or fill. Then you can keep on adding to or subtracting from your rod reading at grade the change for each station, and work from rod readings at grade entirely, paying no attention whatever to your height of instrument or grade height until ready to move your instrument, when you begin over again. In this way one can soon become so familiar with the work that he can call off and record his work as fast as a rodman and two smart men can measure the distances, mark and drive the stakes.

In cross-sectioning at changes of grades, especially when the changes are abrupt, vertical curves should be put in, extending from 1 to 3 or 400 feet each way, so as to avoid bringing the connecting grades to a point. This introduction of vertical curves is very little extra trouble in connection with the other work and should not be neglected. It is also advisable, though not a necessity, to put in at each regular station, where fills are to be made from side ditches, *berm stakes* the specified distance out from the slope stakes, as workmen are less liable to cut away the berm if stakes are driven for them to work to.

Earthwork. — Cross-sectioning being done at any given point, the work of grading may be commenced. I have known of grading being begun without any cross-section work, or even the center stakes being in, but cannot say it was a success. Fills should be made from the adjoining excavations within an economical distance for hauling, which

distance varies with circumstances. The embankment should be carried up uniformly from the bottom from full width, so as to prevent sliding or uneven settling. Fills made from cuts by the use of dump-cars can be carried up uniformly by shifting the track as may be required; where fills are made from side ditches the latter should be taken out continuously so as to make clear waterways where necessary. The usual slope given to ordinary earthwork of sand, clay, or loan, is $1\frac{1}{2}$ feet horizontal to 1 foot vertical, although varying circumstances may make a greater or less slope desirable. In cuts, the slopes should be smoothly dressed and uniform; in each cut, however small, there should be side ditches to carry off the rain-water, or that which soaks in from the sides; the ditches should have a surface width of one-half the difference of the width of cut and fill at sub-grade, leaving, as it were, an embankment through the cut, so that, when the earthwork is completed, the grade presents an unbroken surface of uniform width. It is not always advisable during the process of construction to take out cuts to the full width, or even down to sub-grade; when the material may be used for ballast the cut may be *gulleted* or taken out just wide enough to admit the passage of a train, and with slopes of $\frac{1}{2}$ to 1, or even steeper, if the material will allow, and the remainder of the cut taken out with trains. In certain cases it is advisable to build narrow banks at first, to be widened later on.

Across all swamps and marshes soundings should be taken to determine the nature of the ground and the depth to firm bottom, and, in case the foundation is not good, some means should be taken to improve it. Where it is not too soft or too deep, a good method is to corduroy with timber laid cross-wise of the road-bed with brush thrown on; the length of the timber necessary may be judged from the nature of the ground and the weight of embankment to be built. In some cases it is necessary to drive long piling, and some swamps are so deep that it is almost impossible to build across them with any reasonable expense, such places should be avoided if possible. Across some swamps and marshes very little or even no material may be obtainable to make a bank. I have recently, in my own experience, met with a swamp $2\frac{1}{4}$ miles across, which was, in the direction of the line, a level surface; soundings showed a firm bottom 6 to 18 feet below a fairly firm muck; but the season was very wet, and an attempt to throw up a bank of muck was a failure, as it would run off a shovel before it could be thrown up. In this case I took the small poles and brush from the right of way and laid them along the center line cross-wise, and then some small poles, from 2 to 6 inches in diameter, lengthwise, so that they would come under the ties outside the rail; on these I laid the ties and iron for a good share of the distance across the swamp, with no earthwork whatever. After the track was laid across (it was not very smooth however), we turned back and filled with clay and raised the track; soon it will be one of the best pieces of track on the road.

Culverts.—During the process of locating and constructing, the engineer has looked over his line and its contiguous territory closely, to determine the location, size and character of the necessary water-ways, and during his cross-section work has probably staked out his drains, culverts and bridges, made out his timber bills, and made provision for the timber and material for the various structures. In places where there is but a small area of surface drainage, and no danger of an accumulation of water, a small drain of sewer-pipe may be made, or in cases where cheapness of construction is necessary, which too often happens, a simple box of plank, spiked together, will answer where the embankment is light. Where there is much water a culvert should be put in. On new work in new countries wood is almost entirely used, leaving the more expensive as well as more desirable stone and iron structures to be put in when the first have had their day, and the other can be brought to the spot by train, and the company have presumably more means to do work with.

Ordinary culverts are built of $12'' \times 12''$ timber; I use $10'' \times 12''$ on edge, the sticks laid one upon the other, secured by dowel pins. The foundations are usually ordinary mudsills of flatted timber, sunk in the ground below the bottom

of the waterway, to avoid undermining. The sills should be boxed down at the ends for a couple of inches to prevent the wall sticks from sliding in from the pressure of earth behind them. The top wall piece of an open culvert should be 4 feet longer than the width of embankment of sub-grade, and each succeeding stick 3 feet longer than the one above it till the surface of the ground is reached. The walls should be braced against the thrust of the earth behind them by struts across from one wall to the other, usually dove-tailed into the wall sticks. Culverts should be laid out so as to have the top of the walls reach just to sub-grade; on these walls are laid the track-stringers, lying loose so as to be brought to the required line or shifted at any time. When open culverts are more than 8 feet wide they should be made with a bridge top, *i. e.*, with ties across the stringers. Box culverts are made as above described, but are covered with either plank or timber, and usually with the earth of the fill. Across small streams the ordinary pile bridge is the cheapest and best to build. Use white oak piles, not less than 10 inches in diameter at the small end, well driven; the usual plan has 4 piles in a bent, the bents from 12 to 16 feet apart (14 feet is a good distance), the piles sawed squarely off and the cap securely drift-bolted on top of the piles. Where the height does not exceed 12 or 15 feet the piles may answer as bents, and the track-stringers be laid directly on the caps; but where the height is greater there should be trestle-work on top of piles. Across larger streams, or where there is danger of freshets, ice, driftwood or logs, there should be a clear span to leave the channel unobstructed; on navigable streams a draw-bridge becomes necessary. For ordinary trestle-work, timber of the following sizes may be used: Caps 10×12, main posts 10×10, batter-posts 8×10, stringers 7×14, lateral braces 6×6, sway braces 3×10, girts 6×6, ties 6×8, guard rail 6×6. These dimensions will suffice for narrow-guage roads using engines of 18 to 20 tons weight; we have latterly built our bridges of the usual standard size.

Track-laying.—In advance of track-laying the engineer should carefully retrace his line along the grade, and put in solid stakes for track centers. These stakes should not be less than 2 inches square, well driven, left 6 to 8 inches above the surface of the grade, and having a tack or nail showing the exact line on the stake. On tangents center stakes 200 feet apart will suffice, but on curves they should be put in every fifty feet. Centers should be put on all culverts, and at intervals of 10 to 20 feet on all bridges. We will now suppose the centers in, the material all ready, our forces and construction trains at hand, and will proceed with work. First, we must load one train with the proper proportion of iron, ties, bolts, straps, spikes and tools; the car for bolts, straps, spikes, etc., is usually the head car, then come the ties, then the iron. The train is backed out to the end of the iron, and when the track-laying force is ready, as many rails and ties as will make a lorry load are thrown off, together with the necessary spikes, bolts and straps, and the train pulls ahead out of the way. The lorry men run their car back and load, say, ten rails; above the rails, but placed so as to leave the rails loose, are loaded a sufficient number of ties for as much track as the rails will lay, and bolts, spikes and straps enough for ten joints. Then the lorry is run ahead to the end of the rails, where the men, standing in a row on each side, pass forward the necessary number of ties for a rail length, laying them evenly and properly spaced on the grade, being guided by a line stretched along the grade and a pole properly spaced; a large tie should always be selected for the joint. Next, on each side, the forward gang grasp the end of a rail and pull it forward, and, as the rear end drops from the lorry, it is caught by the rear gang and placed at the end of the rail in the track, then the forward end is dropped to line; this is done on each side simultaneously; the lorry is then run ahead to the end of the two rails just laid and the process repeated. While this work has been going on, another lorry load of iron and ties has been loaded and brought forward, the empty lorry tipped on its edge off the track to allow the other to pass, which, in its turn is unloaded and sent to the rear for another load. For laying light rails three men at front and two at rear on each side is force enough; for heavy iron more are necessary. As the iron

and ties have been run out from the lorry a pair of straps, with the necessary bolts, has been left at each joint, and two spikes dropped at each end of each tie.

Immediately in the rear of the lorry come the *strappers*, who quickly place the fish-plate, or whatever joint fastening may be used, on the joints, and bolt them to place, leaving the proper expansion at each joint; then come the *spikers*, working two together, the two on the line side ahead, spiking usually the joints, quarters and centers. Before the train is run upon the track each rail is spiked to the tie exactly to a line which a boy has previously chalked on it a certain distance from the end, measured by a short stick, so that when the rail is full spiked and lined, the line end of the ties are in a true and even line. The rail joints should be kept exactly opposite to each other, except on curves, when joints should be opposite centers on narrow-gauge track, as it thus retains its alignment much better. Two spikers are also at work on the other side, using a gauge, and quickly spiking the rail to place; each set of two spikers have with them a *nipper*, or a man with a light iron bar and a block of wood, whose duty it is to hold the tie to the rail while being spiked. Spikes should be driven squarely into the ties so as to have a firm bearing against the rail, both on the side and head of the spike, and should be driven, not in the center of the tie or exactly opposite on the side of the rail, but one a little ahead of the other, but both inside spikes should be driven alike, *i. e.*, either ahead or back of the center of the tie, as it prevents the tie from *rocking*, which it will do if spiked otherwise. As soon as the track is laid and spiked at the joints, quarters and centers, the train may be run up and kept closely following the workmen. Behind the train come the back spikers, who complete the spiking, and then the *liners*, who throw the track into line, when it is ready for the ballast train. Track-laying is often partially done by machinery, by means of adjustable rollers fastened to the sides of the car, on which the iron and ties are carried to the front along the side of the train; also by a lorry car running on a track on the supply train. Each method has its advantages, especially where men are scarce.

Ballasting.—As soon as the track is laid the engineer should run his ballast grades, which should be marked by good stout stakes set at the side of the grade, at the foot of the slope of the ballast opposite the center stake, and driven so that the top of the stakes should be as high as the top of the rail at final grade; stakes 200 feet apart on tangents and 50 feet on curves, the same as centers, will answer. The ballast train should consist of as many flats as can be conveniently used and handled, varying with the condition of the pit for loading, the capacity of the engine for hauling, and the force used to do the work. The most economical method, when a convenient pit of material is reached, is to lay a temporary track (or, what is better, if it can be done, two tracks into it, by which much time will be saved in shifting trains), then load one train while the other is on the road. Unloading is most economically done under ordinary circumstances by means of a plow worked by a wire cable from the engine, when no time is lost by men riding back and forth between pit and unloading point, as the train force is sufficient to handle the plow, and the pit force can be adjusted so as to load while the train is making a trip. An estimate of the quantity of ballast to be used should be made, so that the trainmen may make a proper distribution of it. Allowing the surface to be uniform at sub-grade, the quantity of ballast to raise the track to final grade can be determined very closely and distributed accordingly, so that, when the surface is complete, very little or no ballast will remain unused.

In raising track it should first be lifted to final grade at each grade stake and securely packed; then by use of sighting boards, the joints and centers between the two points are raised to the same grade, except on the vertical curve before alluded to when the intermediate points should be rounded to agree with the curve. On horizontal curves the outside rail should be raised; on 3-foot gauge we raise the outer rail $\frac{3}{8}$ inch for each degree of curvature up to 5°. All points of the track having been raised to the proper height, and the ballast shoveled in and well tamped the entire length of each tie, the track is ready for lining. A liner and three or

more men with lining bars throw the track carefully to the exact center as indicated by the tack head in the stake driven before track laying; then all parts of the track are thrown to correspond, and the rail brought to a true line. One side (it is not essential which) should be taken as the line side, and all lining of ties, iron, or track be done on that side. Following the liners come the finishers, who properly distribute what material may be left by the surfacing gang, and give the required surface to the ballast, dress it up neatly, remove any ballast from the ditches in cuts, and gather up in shape for removing any surplus material. Different companies have different forms of ballasting and dressing. Some raise the ballast nearly as high as the top of the rail in the center and slope it to the lower edge of the tie at the end; others keep it nearly level with the top of the tie in the center, and nearly as high at end of the tie, and others still have other forms; but on narrow-gauge track it is essential that plenty of ballast should be at and against the ends of the ties, otherwise it will be very difficult to hold the track in line.

Very many points of work have not been alluded to at all, although they all have an important bearing upon the work. We have not mentioned at all what is important, especially to the contractor, monthly and final estimates, also the manner of making them, building of bridges, crossings, etc., and the thousand and one other matters that enter into the work of construction.

Equipment.—But let us consider our road-bed and track as completed, ready for the running of regular trains, and mention some of the necessary equipment for doing business. Of first note is the rolling stock, consisting of locomotives, passenger coaches, baggage, and express cars, box cars, flat and stock cars. The locomotives should, of course, be adapted to the service for which they are intended; those for the passenger service should have a larger wheel and quicker motion than those for freight; so of the other rolling stock, it should be adapted to the class of business required; but I leave the subject of rolling stock for some one better acquainted with it than I am, and mention briefly some of the equipment which more directly concerns the engineer, such as water stations, passenger and freight buildings, shops, engine houses, turn-tables, etc.

About the first essential is the water supply for engines. During construction work, the engines may be supplied with water pumped by hand directly into the tender tank, or better still by a small steam pump, which may be shifted from point to point, or yet again by a steam siphon and hose carried with the engine, the hose of which can be dropped into any convenient ditch or pond of water by the roadside; in case of emergency, water may be bailed up with pails. All these processes are slow and tedious, and will not do for permanent use. Locations should be chosen at convenient points, at stations or regular stopping places, not exceeding 20 miles apart—15 is better—and tanks of sufficient capacity put up. Tanks of from 20,000 to 30,000 gallons' capacity will answer where traffic is not very heavy, or even less would do, but small tanks are not advisable, as the supply is not as lasting, and in severe weather is more liable to freeze. The tanks should be erected upon a framework of posts of convenient height, so that the drop pipe will have a good sharp incline when water is being taken. For a tank of 20,000 gallons 12 posts $8'' \times 8''$ in size are sufficient; the foundation may be of stone or of piles capped with $8'' \times 8''$ for sills, the posts framed into them, and capped at right angles to the sills with $8'' \times 8''$ caps; on them rest the floor joists, and on the joists directly the bottom of the tank, the joists being cut away for the chime of the staves; a tank holding from 20,000 to 30,000 gallons, should be made of 3-inch staves and bottom. To make the tanks frost proof, all that is necessary is to put in a ceiling 18 inches below the top of the staves, and pack it with 18 inches of good sawdust, leaving the space between the top of the staves and roof, which should be perfectly tight, as a dead air space; also to pack it well around the supply, waste, and delivery pipes and under the floor; in extreme cold weather it will of course freeze a little, but not enough to do any damage. There are many different methods of supplying the tanks with water; that most in use is by a small steam pump; wind power is also quite extensively used and is considered quite economical, although

my experience has been that it lacks in that respect and is not altogether reliable. Hot air engines are also somewhat used, and I believe are considered economical and reliable. Our company have had one in use at Vassar for the last six or eight months, and are well pleased with its performance thus far. Too much care cannot be taken to have good water and a supply that is permanent. Soft water from streams is considered the best; water containing minerals, especially lime and other substances that coat boilers, should be avoided.

Station buildings come next in importance to water stations, if indeed any gradation in importance can be made; for successful and economical operating all are required. It may be supposed that, during the process of construction, the location has been chosen and the grounds secured. Usually, during the first excitement of the enterprise and the rivalry of the different centers or villages in their efforts to secure the road, a choice of location can usually be had, which should be made with reference to the convenience of access, and economy and convenience of laying out the sidings and arranging for the business of the company. It is well to secure ample room at first, for, after the grounds are once secured, it is strange how soon contiguous property appreciates in value, and often it is impossible to obtain more room without buying at exorbitant prices. The station building should be of sufficient size to accomodate the business of the place. In small places, where one man does all the work, I think it advisable to unite the passenger and freight buildings in one, as it is more economical as well as convenient. For places of only a hundred or two of population, where business interests are not very great, I have found a building 16×40 feet in size to be ample.

A convenient one is built as follows: 16×40, with 12 foot walls, the interior divided in the middle by an ordinary studded partition, making the freight room 16×20, and 16×20 for a waiting room and office; the office is made by running a lattice partition across from floor to ceiling, 6 feet from the end of the room. This lattice partition allows the waiting room stove to do duty for the office as well,—another item of economy, as you will please bear in mind that I am speaking especially of the equipment of a narrow gauge road, where cheapness and economy are a desideratum. In front of the office is a bay window, so that the agent or operator has full view of the track each way. In front of the building the platform should be not less than 12 feet wide; we build it 1 foot above the rail with a raised portion 8 feet wide in front of the freight room, and raise the freight room floor above the waiting room floor so as to be on a level with the floor of a box car; the platform across the end and rear of freight room is level with its floor and descends again to the level of the waiting room by an easy incline. For a place of several hundred inhabitants, we build a station 20×70 feet in size, similar to the former with the addition of a baggage room; and in large places make them 20×100 feet or more. Where two waiting rooms are needed we build the office partially between the two, so as to give convenient access to both. We have found the system of passengers and freight in the same building to work satisfactorily, having in no case, except at terminal stations, any other arrangement, although in very large places it would not be desirable. During construction the engines are usually left standing out of doors with no covering whatever; sometimes a rough temporary shed or engine house is built; but it now becomes necessary to have permanent buildings for them. Such are usually built in a partially circular form, with stalls or divisions to accomodate one engine each. A suitable location is chosen, and a turntable put up, and, radiating from it as a center, the tracks enter each division of the engine-house; underneath each track, inside the house, is built a pit for convenience in working at the under side of the machinery. These houses are usually built of either brick or stone, although cheapness of construction being often demanded, wooden ones may be built with simply a frame work of 8″×8″ posts, with 8″×8″ caps, 2″×6″ studding, 2″×10″ and 12″ joists; they should be sheeted around the outside, then papered with heavy building paper, then boarded and battened. Double doors in front of each division may be built on a light frame of 2″×4″ in the same way; a tar and gravel roof will do as well as any. At terminal stations and points where engines are

kept for yard or other service a small building of sufficient size for the required service should be built, and may be located over an ordinary spur track in a convenient place. At headquarters, in connection with the engine or round-house (as it is usually called from its partially circular form), should be the repair and machine shops, the size, equipment, and capacity of which will depend on the number of engines to be kept in repair, and the amount of work to be done; the more complete they can be made as to machinery and appliances, the more economically can the work be done, although of course due regard must be had to the means to do with. It is also necessary to have car repair shops and a place for storage of coaches when not in use. A supply depot is almost a necessity on a road of any importance. It is also necessary that a road should be furnished with the necessary sidings at different points along its line, and yards at terminal and important points for the storage of cars, etc.

Cost.—I am aware that I am already making this article too long and am only touching upon a point here and there, so perhaps I had better close by giving an estimate of the various items of cost that are applicable to a narrow gauge road, as very little of what I have already said will not apply to any gauge of railroad. First the right of way must be secured, which, through a farming and timbered country, like the lower peninsula of Michigan for example, will cost from $20 to $50 per acre, although usually from one-half to three-quarters can be secured as a donation. However, we will say an average of $40 per acre, which gives, for a right of way 4 rods wide, 8 acres or $320 per mile. Clearing through the average country above alluded to can be done for $25 per acre, or $200 per mile, and grubbing will average perhaps $100 per mile, though in heavily timbered land it will cost very much more. A fair price for ordinary earthwork is 25 cents per yard, and at 5,000 yards per mile, (although on the P. H. & N. W. Ry., of over 200 miles, the average has been less than 4,000 yards per mile), we shall have for earthwork $1,250. Bridges, if not too expensive, may be figured $200 per mile and culverts at $100. This will give for right of way and road bed as follows:

Right of way	$320
Clearing	200
Grubbing	100
Earthwork	1,250
Bridges and culverts	300
Total	$2,170

Ties will cost, say 20 cents, although the average price paid for more than half a million ties used by the P. H. & N. W. Ry., has been but little more than 10 cents.

2,640 ties per mile at 20 c.	$528.00
Rails, (steel) 35 lbs. per yard, 55 tons per mile, at $50 per ton	2,750.00
Fish plates, 532 pairs, weighing 8 lbs. per pair, at 3 c. lb	127.08
1,408 bolts, ½ lb. each, at 4 c.	28.16
Spikes, 27 kegs per mile, 150 lbs. per keg, at 3 c. lb. (now considerably less)	121.50
Track laying per mile	200,00
Ballasting, 35 c. yard 1,100 yards per mile	385.00
Making per mile	$4,139.74
To which we must add about 5% minimum for siding, etc.	206 98
Total per mile	$4,346.72

We will perhaps arrive at a better result for equipment by considering the amount needed for 100 miles of road. Let us say,

8 locomotives, from 14 to 20 tons @ $8,000 each	$64,000
6 first-class coaches @ $3,000 each	18,000
6 second-class coaches @ $2,300 each.	13,800
4 baggage and express cars @ $1,700 each	6,800
150 box cars @ $325	48,750
10 stock cars @ $350	3,500
50 flat cars @ $225	11,250
Hand-cars	900
Total for rolling stock	$167,000

or $1,670 per mile.

Water stations at terminal stations, and 4 intermediate on the 100 miles will cost $700 each	$4,200
For station buildings we will say 12—6 of the smaller size mentioned, which, with the platform and outbuildings complete will cost $600 each	3,600
Four, 20′×70′ in size @ $1,000 each	4,000
Two, 20′×100′ in size @ $1,300	2,600
Larger passenger and freight buildings at headquarters costing	15,000
Engine-house of 8 stalls at headquarters.	2,000
Small engine-house at other end of line.	500
Two turn-tables @ $600 each	1,200
Machine shops and machinery	10,000
Car repair shops	6,000
Coach house	1,000
Telegraph line	5,000
Total	$55,100

or $551 per mile. Making a summary as follows:

Right of way, road-bed, etc., per mile	$2,170.00
Ties, iron, track-laying, ballasting, etc.	4,346.72
Rolling stock equipment	1,670.00
Buildings	551.00
Fencing	600.00
Making a total per mile of	$9,337.72

to which may be added engineering and contingent expenses, which will make in round numbers at least $9,500 per mile.

ON THE ANTISEPTIC TREATMENT OF TIMBER.

By S. B. BOULTON, Assoc. Inst. C. E.

From "The Engineer."

The author commenced by referring to a paper by his late partner, Mr. H. P. Burt, Assoc. Inst. C. E., on the subject of timber preserving, which had been read at the Institution in 1853. Since that date the use of antiseptics for the treatment of timber had greatly increased. The process called creosoting, or the employment of the heavy oils of coal tar, had almost entirely displaced the other methods, whilst the manufactures connected with the residual products of gas making—from one of which residuals the creosote oils were derived—had experienced an enormous development. The author's connection, during thirty-four years, with this group of industries enabled him to offer the results of some personal experience and research, which he presented, together with those arrived at by other investigators. An historical description of the antiseptic treatment of timber was preceded by a few notes on the method pursued by the ancients for the preservation of wood and other perishable materials. The ancients were well acquainted with the manufacture and use of many kinds of oils, tars and bitumens, and frequently used them for the preparation of wood, with respect to which some notable instances were cited. The methods employed by the Egyptians in embalming their dead were dwelt upon at some length, and the author endeavored to elucidate some discrepancies in the descriptions of these processes, as recorded by Herodotus and Diodorus Siculus. The researches of Petigrew were alluded to, particularly his interesting experiment upon the heart of a mummy, which, after three thousand years' preservation, began immediately to putrify when the antiseptic substances were removed by maceration. This appeared to prove that no chemical transformation had taken place, but that the long immunity from decay had been the result of the abiding presence of the antiseptic. The growth of theories upon the causes of putrefaction was traced down to the commencement of the present century, reference being made to the "Phlogiston," and other exploded theories; also to the opinions of Macbride, Sir John Pringle, Sir Humphrey Davy, Thomas Wade, and others, and to their suggestions upon timber preserving. The progress of timber preserving during the railway era, and particularly between the years 1838 and 1853, was described, with especial reference to the competition between the four most successful of the processes. These four consisted in the employment of corrosive sublimate, sulphate of copper, chloride of zinc, and heavy oil of coal tar, which had been patented in England respectively by Mr. J. H. Kyan, Mr. J. J. Lloyd Margary, Sir William Burnett, and Mr. John Bethell. The distinction was pointed out between the real creosote—a product derived from the distillation of wood, but which had never been employed for injecting timber—and the so-called creosote which had been so successfully used for that purpose, the latter being a heavy oil produced from the distillation of gas tar. The theory that certain antiseptics preserved timber by coagulating the albumen, and by forming insoluble combinations with the woody fiber, had been advanced on behalf of all the four processes alluded to. But, in spite of some acknowledged success, the Kyanizing

Margaryizing, and Burnettizing systems were not found to be so durable in their effects as creosoting. Indeed, the salts of metals were gradually washed out of timber exposed to the action of water. On the other hand, the success of the creosoting process became completely established. In order to show the process of manufacture of the creosote oils, a short description was given of the ordinary methods of tar distilling. Coal tar, a black, viscous substance, was a residual product of gas making. It was split up by a preliminary process of distillation into three groups of substances, namely: (1) Oils lighter than water, containing the naphthas, benzoles, toluols, and other bodies, from some of which the aniline dyes were manufactured. This series of oils had never been used for timber preserving. (2) Oils heavier than water; the dead oils or creosote oils of the timber yards. These oils contained a great variety of different bodies, the properties of some of which were described, including carbolic acid, cresylic acid, naphthaline, anthracene, crysene, pyrene, quinolene, leucoline, acridine, cryptidine, &c. (3) Pitch, the residuum of the distillation. The creosote oils varied in their characteristics in different districts, according to the nature of the coal used in the gas works, and to the varying temperatures at which the coal was carbonized. The type of creosote called "London Oil," made from the tars derived from the coal of the Newcastle district, was contrasted with the so-called "Country Oil," typical of the product from the tar of the Midland and other coals. The former contains less of the carbolic and cresylic acids than the latter, but more of the semi-solid substance, which solidified within the pores of the timber, and more of the antiseptics which did not volatilize except at exceedingly elevated temperatures. The history of the controversy as to the respective merits of the two types of creosote oils was fully gone into. The carbolic and cresylic acids had been recognized as potent antiseptics; their presence appeared to arrest the action of all destructive germs, and the lighter and thinner country oils, which contained a comparatively large percentage of these tar acids, had therefore been preferred by many. The opinion of Dr. Letheby to that effect was recorded. On the other hand were cited the opinions and practice of the introducers of creosoting and of the earlier operators in that process, who used in preference the heavier types of creosote; and the early success of that creosote, both in England and in tropical countries, appeared to confirm their judgment. A number of experiments were then alluded to, stretching over a long series of years, and conducted by investigators in this and in other countries for the purpose of ascertaining which of the component portions of the creosote oils were the most durable and efficient agents in preserving timber. The result of these experiments appeared to show that it was not to the tar acids, but to the heavier and least volatile portion of the creosote, and to those bodies which solidified within the pores of the timber that the most durable results should be attributed. This apparent anomaly was explained by reference to numerous eminent authorities upon carbolic acid, who, whilst extolling its action as a most useful and powerful antiseptic for sanitary and surgical purposes, were in general agreement as to its possessing the following characteristics: That it was exceedingly volatile at ordinary temperatures, that it was readily soluble in water, and that its combinations with other bodies, including albumen, were not stable. It would, therefore, readily evaporate from timber exposed to the heat of the sun, especially in warm climates, and it would be washed out of timber in contact with water. The author's personal experience and experiments fully bore out the conclusion that the use of the heavier and least volatile portions of the creosote oils should be encouraged, and that from them the most durable results might be expected. Moreover, it was pointed out that recent investigators had discovered in these heavy oils, bodies which, if perhaps less potent, were more durable in their antiseptic effects than carbolic acid. By judicious selection and admixture, both London and country oils could be usefully employed. Shale oil and bone oil, however, and other oils lighter than water, should be excluded. The modern germ theory was discussed in its relation to timber preserving, and was believed by the author to be a more practical ex-

planation of the action of antiseptics upon wood than the older theories as to the coagulation of albumen and the formation of insoluble compounds. With respect to all bodies which had been extensively used for timber preserving their durable results appeared to be in an inverse ratio to their volatility in the atmosphere and their solubility in water. The germ theory constituted a severe but salutary test in choosing antiseptics for the treatment of wood. In the author's opinion the substances preferred should be not only germicides, but germ excluders, those being the best which were least soluble in water, least volatile in air, and most capable of becoming solid within the pores of the timber. A description followed of the various kinds of apparatus which had been in use during the present century for injecting timber with antiseptic liquids. The paper concluded with some remarks upon the subject of the hygrometric condition of timber at the time of injection, failures having repeatedly arisen owing to the timber being too wet at the time of creosoting. The author dwelt upon the importance of this subject, describing also his experience with various methods of getting rid of superfluous moisture artificially, and of a process which he had recently inaugurated, by which this result could be obtained in the creosoting cylinder itself, without injury to the timber.

The paper was illustrated by diagrams showing the most important products derived from coal, and the apparatus for coal tar distillation and timber preserving; also by tables, giving the properties of coal-tar products and other substances, of timber-preserving specifications, and of more than one hundred references to various authorities upon the topics alluded to in the paper.

THE MANUFACTURE OF CRUCIBLE CAST STEEL.

By HENRY SEEBOHM.

Transactions of Iron and Steel Institute.

The old-fashioned method of converting bar iron into steel, and afterwards melting it in clay pots to form ingots of cast steel, which are reheated and rolled or hammered to the size and shape required, has been so frequently described that I should not have ventured to bring the subject before the notice of the members of the Iron and Steel Institute had I not been requested to do so by the council of the society. It was suggested that, inasmuch as the *Journal* of the institute did not contain a paper on this subject, the occasion of the annual meeting of the members being held in the town of Sheffield, the headquarters of the crucible cast steel trade, would present an appropriate opportunity for collecting the facts connected with such an important branch of industry. These facts may perhaps be all the more interesting now that Sheffield has somewhat ungraciously failed to respond to the wishes of the institute; not in the least degree from want of hospitality, but from a deeply-seated belief that the Patent Laws are so bad that it is more profitable to keep secret a mechanical improvement than to patent it. Sheffield inventors have learnt by bitter experience that secrecy is the only protection for improvements; and if they think that they have found a goose that is going to lay golden eggs they lock and double lock the fowl-house door. It is said that there is no Act of Parliament through which you cannot drive a coach-and-four, and I am afraid that the Patent Laws are no exception to the rule, if you only have sufficient money to buy a strong enough team. I may premise that I have nothing new to bring forward. No Sheffield firm has yet succeeded in discovering the philosopher's stone. We all have our little secrets, which we jealously guard (and they have no greater scientific value than the secrets of the Masonic fraternity), but in spite of the important and valuable discoveries which have been perfected during the last quarter of a century in the methods of producing cast steel, the old-

fashioned crucible steel manufacturers of Sheffield still hold their own. They still convert bar iron into blister steel, and melt blister steel into cast steel, and some of them have not been altogether unsuccessful in transmuting cast steel into gold.

The accumulated experience of a century has convinced the manufacturers of crucible cast steel that the finest qualities can only be made from bar steel which has been converted from iron manufactured from Dannemora ore. This iron is expensive; its average cost for the last forty years has been at least £25 a ton; the process of converting it into steel is slow and costly; the process of melting in small crucibles is extravagant both in labor and in fuel, and consequently the best qualities of crucible cast steel can only be sold at a high price. So-called best crucible cast steel is sold at low prices by unscrupulous manufacturers, and bought by credulous consumers, but though it is quite possible for high-priced steel to be bad, it is absolutely impossible that low-priced steel can be good. The finest quality of steel cannot be made of cheap material or by a cheap process. Every year the attempt is made, and every year it signally fails. No one ever made a better try than Sir Henry Bessemer, but his failure was as complete as that of his predecessors. He attempted to produce an article at £6 a ton to compete with one at £60 a ton, and failed absolutely. It is true that his steel is a success, perhaps the most brilliant success of the century. I am not quite sure that he himself believes in his failure. In his lecture before the Cutlers' Company of London, in 1880, he chaffed the steel manufacturers of Sheffield on their antiquated attachment to the rule of thumb, and twitted them with the assertion that the high price of crucible cast steel arose from a combination of trade interest on their part and of prejudice on the part of their customers. Sir Henry Bessemer may have half ruined the wrought-iron trade, and revolutionized the pig-iron trade, but the crucible cast steel trade holds its own in spite of his great discoveries. When railways were first introduced, and wagons and coaches were to a large extent driven off the road many people thought that the price of horses would permanently fall, but exactly the contrary took place. Similar fears were entertained that the demand for crucible cast steel would seriously decline when Bessemer and Siemens steel came into the market. This has not been the case. The commoner qualities of crucible cast steel have been, to a large extent superseded by Bessemer and Siemens steel, but the enormous quantities made by the latter processes have required for their manipulation, directly or indirectly, such a large quantity of the better qualities of crucible cast steel, that the total amount of the latter now produced in various parts of the world is probably double that which was required before the birth of its rivals.

Chemical analysis plays a very important part in the manufacture of iron, Bessemer and Siemens steel, and even of the comparatively small quantity of crucible cast steel which is still used for purposes in connection with which it is not required to be hardened and tempered. It is possible to judge very accurately of the quality of those metals from their chemical analysis, almost as much so as from the results of mechanical tests, such as the breaking strain and the contraction of the area of fracture. But in what we may call, for want of a better name, the legitimate cast steel trade, chemical analysis, though it tells us a great deal, does not tell us everything. The analysis of steel shows the amount of other ingredients which it contains besides the nine-tenths or more of iron which forms its basis. The amount of carbon, silicon, manganese, sulphur, phosphorus, copper, &c., may be ascertained with tolerable accuracy, and the information thus obtained is often of the utmost importance; but it is quite possible to make a comparatively low-priced steel which shall show precisely the same chemical analysis as the best crucible cast steel; nevertheless it is found by practical experience to be inferior in quality. That this is a fact has been proved over and over again beyond all possibility of doubt. It is a sufficient reason why Sheffield manufacturers have been willing to pay such a high price for Dannemora iron for so many years; but it is not a sufficient reason why so many Sheffield manufacturers should ignore the results of chemical analysis altogether. Of every fact there must be

some explanation, though we may, for the present, at least, be ignorant of it. To say, with the Sheffield devotees of the rule of thumb, that the one steel possesses "body," and that the other does not, explains nothing, but merely adds to the synonomy of the subject by altering the nomenclature. If the metallurgical chemists could once convince themselves that this difference in quality is a fact, they would probably soon be able to give us an explanation. We already know much of the chemistry of steel, and what remains to be learnt is as certain to be some day discovered as the fact that Newton discovered the laws of gravitation. Mathematicians may never discover how to square a circle, mechanics will never discover a perpetual motion, nor will chemists ever discover the transmutation of metals; but the discovery of the chemical explanation of "body" is only a question of time. By way of stimulating enquiry I venture to suggest two possible causes of body which may be worth consideration as a tentative hypothesis of its nature. The best razor-steel contains one and a-half per cent. of carbon. It must be melted from evenly converted steel. It will not do to mix hard and soft steel together, or to melt it from pig "let down" with iron, though in either case the exact one and a-half per cent. of carbon may be the result. Steel made by the latter processes will not possess the requisite amount of body; consequently, the cutting edge of the razor will not stand. It must be melted from steel converted from iron made from ore containing manganese. It will not do to add the manganese in the form of spiegeleisen or ferro-manganese. Carbon and manganese exist in combination with iron not chemically combined in certain definite proportions, but as alloys, as mechanical mixtures in any proportion. We know that carbon exists in combination with iron in two forms, either as combined carbon or free carbon; is it not possible that manganese may also exist in two forms, and though the razor steel must have been boiled in the pot for half an hour after it was melted, to kill it and make the ingot pipe, is it not possible that the mechanical mixture of the carbon and the manganese is less homogeneous in steel made by the cheap processes than it is by that made by the old-fashioned method? It has been stated that the finest qualities of steel when hardened show a more perfect regularity in their crystallization when examined under a microscope than commoner qualities, and I venture to suggest that a possible explanation of "body" in steel may be absence of injurious ingredients, combined with the perfectly homogeneous presence of the advantageous ingredients. Hardened steel is crystallized steel; and perfect regularity of crystallization in steel which is required to be ground to a fine cutting edge may be a necessity which can only be secured by the slow and expensive old-fashioned method.

The principal reason why Bessemer and Siemens steel have failed so completely to supersede crucible cast steel for purposes where the better qualities are required, is that they cannot be made sound without the addition of silicon or manganese. In melting common steel (containing, for example, from 0.15 to 0.05 per cent. of phosphorus), the steel must be poured into the mould as soon after it has become perfectly fluid as possible, and as hot as the tensile strength of the pot will allow. In making the higher qualities of crucible cast steel (where the percentage of phosphorus ranges from 0.01 to 0.001) a similar mode of treatment would produce very strange results; the molten steel would boil over in the mould, the fracture of the ingot when cold would show a series of bubbles like a sponge, and its specific gravity would scarcely exceed that of wood. Some of these bubbles or honey-combs would weld up when the ingot came to be forged, but by far the greater number would be coated with an oxide, which would make a weld impossible, and the bar, if it was not burnt up in the fire, would be so full of the imperfections technically called "seams" or "roaks" as to be perfectly useless. To obviate this disastrous result it is necessary to boil the steel for nearly half an hour after it has become fluid, and then to allow it to cool down to a certain temperature before it is poured into the mould. This process is called, in the language of the votaries of the rule of thumb, "killing" the steel, and it is an axiom amongst them that the higher the quality of the steel the more "killing" it

takes. It is in this part of the process of crucible cast steel melting that its special virtue consists, and the cost and quality of the cast steel produced depend in a large degree upon the skill brought to bear upon it. There is an old proverb in Sheffield, usually expressed in the terse vernacular of the county, but which may be refined into the expression that if you put his Satanic Majesty into the crucible his Satanic Majesty will come out of the crucible. The converse of this is by no means the case. Though you may convert iron into steel in the crucible, you cannot convert bad steel into good steel in the crucible; but though you may put the most angelically pure steel into the pot, you may, by bad management, by not "killing" it properly, pervert it into satanically bad ingots. Now, this killing of the steel is precisely what cannot be done in the Bessemer or Siemens processes without the addition of such a large amount of manganese or silicon that the steel becomes brittle when hardened. I do not know whether chemists are agreed on an explanation of the necessity for "killing" high-class steel. When iron is made into steel in a converting furnace, it is assumed that the oxygen in the air in the converting pot unites with the charcoal, and is soon made into carbonic oxide, which is occluded by the white-hot iron, and forced by it to part with as much carbon as is sufficient to reduce it to carbonic acid. It has been ascertained that metals have the power of absorbing or occluding many times their own bulk of gas, and possibly the carbonic oxide, when it has parted with the amount of carbon necessary to reduce it to carbonic acid, is not then expelled from the iron, but may remain in an occluded state, and requires to be expelled in the melting pot by boiling. Be this as it may, it is a fact that if it be required to make blister steel harder than about 1.4 per cent. of carbon, it is necessary to convert it twice over, possibly in order that in the interval it may part with some of its occluded carbonic acid, so as to make room for a further occlusion of carbonic oxide.

Another fact which may throw some light upon this question is, that blister steel melted directly after being drawn from the converting furnace requires more "killing" than that which has been exposed to the air for some time, during which it has presumably had an opportunity of parting with some of its occluded gas. The addition of a portion of scrap steel materially assists the process of "killing," as would naturally be the case if we suppose that the scrap (which has been melted before) has parted with its occluded gas in the first melting. The fact that the presence of manganese or silicon helps largely to kill the steel may possibly be accounted for on the theory that the carbonic acid unites with the manganese or silicon, and becomes a solid, or it may be that in an alloy of iron with either manganese silicon or phosphorus, the occluded gas is expelled at a much higher temperature than in pure iron. Before describing the process of making crucible cast steel, it may be useful to devote a few words to the nomenclature of iron and steel. This is almost as much a vexed question as that of zoological nomenclature, and might form the subject of a code of laws, which would probably be as complete a failure as those issued under the auspices of the British Association for the Advancement of Science, which have made confusion in the scientific names of birds and beasts worse confounded. In Sheffield we attempt to discriminate between iron and steel, which we regard as generally distinct, and each of which we subdivide specifically, though it must be admitted that neither our generic nor specific names are very scientific.

Pig iron is melted direct from the ore in a blast furnace, and contains from 3 to 5 per cent. of carbon. When remelted it is called "cast iron," or "metal."

Spiegel iron is precisely the same, but contains in addition from 5 to 15 per cent. of manganese.

Bar iron, often called *wrought* iron, is pig iron which has been smelted and deprived of nearly all its carbon, either in a puddling furnace, or by the Walloon, Lancashire, or other analogous process; the spongy mass or ball of iron is usually hammered or rolled into a bar, which, for the Sheffield trade, is generally 3 inches wide ⅝ inch thick, and from 6 to 12 feet long.

Puddled steel is precisely the same as "bar iron," except that the process of puddling is stopped when rather more than half of the carbon has been re-

moved from the pig iron. There is, consequently, no hard and fast line between bar iron and puddled steel, the one intergrading to the other by imperceptible degrees. Although there are an infinite number of intermediate stages between the softest bar iron and the hardest puddled steel, and although it is impossible to state the exact percentage of carbon which marks the dividing line between one and the other, it is usual to call all puddled bars which cannot be hardened in water, bar iron, and all those which can, puddled steel. This dividing line falls somewhere near a mixture containing a-half per cent. carbon, and although it looks very vague and unscientific to use two terms which thus intergrade, no confusion of any kind, or misunderstanding, has ever been known to arise from their use.

Blister steel is bar iron which has been converted into steel in a converting furnace, and varies in the amount of carbon which it contains from $\frac{1}{2}$ to $1\frac{1}{2}$ per cent. There are of course, an infinite number of degrees of carbonization between "hard heats" and "mild heats," but for the convenience of the trade six of them have been selected, and have received names as follows;

No. 1.	Spring heat......	$\frac{1}{2}$	per cent. of carbon.
No. 2.	Country heat.....	$\frac{5}{8}$	" "
No. 3.	Single-shear heat.	$\frac{3}{4}$	" "
No. 4.	D'ble-shear heat.	1	" "
No. 5.	Steel-thr'gh heat.	$1\frac{1}{4}$	" "
No. 6.	Melting heat.....	$1\frac{1}{2}$	" "

Bar steel is blister steel which has been tilted or rolled down to the size required.

Single-shear steel is produced by welding half a dozen bars of blister steel together. Only those bars are chosen in which the process of conversion has been so far carried on that the outside of the bar is steel, and the center of the bar iron. When these are welded together, and tilted or rolled down to a small dimension, the result produced is a mechanical mixture of iron and steel, a material which combines great tenacity with the capability of carrying a moderately hard cutting edge, and is much employed for certain kinds of knives.

Double-shear steel is produced by drawing down single shear to suitable sized bars and rewelding two of them together, so that the mixture of iron and steel may be more perfect.

Cast steel is steel that has been melted in a "pot" (called a crucible in the encyclopædias), and poured into a mould (called a "form" in the learned books), thus becoming an "ingot," which is afterwards hammered or rolled to the size required. It may be made of various "tempers," varying in the percentage of carbon which they contain from three-quarters or less to one and a-half or more. The different tempers may be arrived at in various ways. For the great majority of purposes there can be no doubt that the best way is to put into the melting pot broken pieces of blister steel converted exactly to the temper required; and the more evenly the steel is converted, and the more carefully all bars which are harder or softer than the temper required, or which are "flushed" or "aired," are rejected, the better. Blister steel, when carefully "taken up" or selected, will produce a cast steel which combines the greatest amount of hardness with the maximum amount of elasticity when hardened. It may, however, happen that for certain purposes "soundness" in the bar, the result of absence of honey-combs in the ingot, may be the most important quality required in the steel; for others, the property of welding most perfectly may be the *sine qua non;* or the great evil to be avoided may be the tendency to water-crack in hardening; or the steel may be used for some purpose where it does not require to be hardened, and the object to be secured is the combination of the greatest amount of hardness and toughness when unhardened. In all cases the mode of manufacture must be adapted to the objects which it is most important to secure. In addition to the mode of operations already mentioned, there are two other ways in which the same percentage of carbon may be secured. You may either put cut bar iron into the pot, and "fetch it up" to the required temper with charcoal, or you may put broken pig iron into the pot, and "let it down" to the required temper with cut bar iron. A fourth *modus operandi*, which, for most purposes is the best of all, might be enumerated, namely, the selection of blister steel slightly harder than the temper required, so as to admit of being slightly

let down to the exact temper by the addition of a small quantity of somewhat milder cast steel scrap.

Bessemer steel or *Siemens steel* do not require definition, nor do they come within the scope of this paper.

The process of converting, or, as it is generally called in the encyclopædias, the process of cementing iron into steel, is carried on in a converting furnace. This furnace consists of two stone troughs, technically called "converting pots," each of them about 4 feet wide, 4 feet deep, and 12 feet long, and placed side by side with a fire underneath them, the flues of which conduct the heat all around each pot. These troughs or pots are built up of slabs of a peculiar kind of firestone, obtained in the neighborhood of Sheffield, and possessing the property of not cracking if heated slowly to a high heat and allowed to cool slowly. The slabs are united together with a mortar made of ground fireclay. Over the two pots is built a vault of firebrick, and the whole is enclosed in a dome of red brick, to prevent as much as possible the heat from escaping. At the bottom of each pot is placed a layer of charcoal, broken up into small pieces, from a quarter to half an inch square. On this a layer of bars of iron is placed, which is covered with charcoal; another row of bars of iron follows, and so on until the pot is filled with alternate layers of charcoal and iron; it is then carefully closed with a thick cover of "wheel-swarf," a silicious species of mud which accumulates at the troughs of the Sheffield grinding wheels, and is, of course, the material of the grindstone, worn away in the process of grinding, and mixed with the finest steel dust which has been ground away, a substance which will resist long exposure to great heat, and renders the top of the pot practically air tight. In order to test the progress of conversion, and to ascertain the precise moment when the fire should be allowed to go out, two or three bars of iron are allowed to protrude through a hole in one of the pots made for the purpose. These bars, technically called "tap bars," are drawn and inspected at or near the close of the process, and are tightly packed in white ashes where they pass through the end of the converting pot, so that no air may find its way to the charcoal inside. The converting pots, full of alternate layers of iron and charcoal, and for all practical purposes hermetically sealed, are gradually raised to nearly a white heat, and kept at about that temperature for a week or more, according to the amount of carbonization required. Another week is occupied in the process of cooling, which must be done slowly, in order to prevent the pots from cracking, after which the cover is broken up and removed, and the bars, which went into the furnace bars of iron, are taken out of it bars of "blister steel," so called from the bubbles or blisters which have arisen on the surface during the process of conversion. Some of the charcoal has been consumed during the week at which it was white hot, but a considerable portion of it remains, and is taken out of the furnaces as black as it went in. A chemical change in the composition of the bars has taken place. They were originally pure iron, or nearly so, containing, perhaps, one-quarter per cent. of carbon, or less, were fibrous in their structure, and would bend double without breaking. After the process of conversion they have become a carburet or carbide of iron or steel, containing from half to one and a-half per cent. of carbon, according to the length of time they have been in the furnace and the degree of heat to which they have been subjected. They are now more or less crystalline in their structure, and can be broken by a slight blow of the hammer. The converting furnaces in use in Sheffield vary in size, some holding as much as thirty tons of iron, and others not more than fifteen tons. The iron gains slightly in weight by being converted into steel. The process occupies about three weeks, and a pair of pots may be used from twenty to forty times before they are worn out and have to be replaced by new ones.

As in every other process connected with the manufacture of steel, in the process of conversion it has to run the gauntlet of many perils. Sometimes the pots crack, air is admitted to the furnace, the charcoal is burnt, and in bad cases even the iron is oxidized. Bars which have thus missed conversion are technically said to be "aired," and even when very slightly affected may be easily discovered, in consequence of their having almost lost

the tendency to become rusty. If the furnace be raised to too high a heat the surface of the bars will melt, and when they are drawn it will appear "glazed." There are even instances handed down by tradition in Sheffield of unskillful convertors, who had heated the furnace under their care to such a degree that the whole mass of iron and charcoal had become fused together, and the end of the furnace had to be taken out to remove the contents. During the process of conversion the outside of the bar of iron is turned into steel the first, and in a spring heat the center of the bar remains iron, though when the bar is broken the crystals of iron have lost their brilliancy; in technical language, the bar is said to be full of "sap," though the sap is "killed," and no longer looks "raw" or "stares." In a country heat the sap is still more killed, and the crystals of steel on the edges have become more distinct. In a single-shear heat the fracture shows more steel on the outside, and less iron in the center, until, in a double-shear heat, the fracture shows about equal proportions of iron and steel. It is important that the transition from one to the other should be as gradual as possible. When the line of demarkation is violent or sudden, the process of conversion has been carried on too rapidly, and bars of blister steel so converted are said to be "flushed." In a steel through heat, as its name implies, all trace of iron in the fracture has been lost sight of, but the crystals of steel are small. A short time longer in the furnace will make the steel a melting heat; the crystals will be large, and in exceptional cases their facets will reach across the bar. The melting furnace consists of a row of oval melting holes, large enough to contain two melting pots, one in front of the other, and deep enough to allow of sufficient coke to cover the lids. From each melting hole a flue leads, in old-fashioned furnaces, into a flat stack, each hole having a separate flue in the stack, but many furnaces are now made with short flues from each hole leading into a main flue which ends in a single square chimney. The application of gas to the melting of steel has been successful, but for the highest qualities coke is principally used, as the control which the melter has over the temperature of each pot, which sometimes requires "keeping back" and sometimes "hurrying on," is supposed to be more absolute. There can be little doubt, however, that the adoption of gas melting furnaces is only a question of time. The furnace floor is on a level with the top of the melting holes; and the grate bars, as well as a flue leading into the chimney, by which the draft may be controlled, are accessible from the cellar. The pots in which the steel is melted are generally made in a room adjoining the melting furnace. They are composed of a mixture of Burton and Stannington clay, to which is sometimes added a proportion of Stourbridge clay, and, if the pots are required to stand a great heat, of China clay from Devonshire. A small quantity of ground coke, as well as of old pots ground, is also added. Great care is taken that the clay be absolutely disintegrated and perfectly mixed together. This is accomplished by treading it in a trough, the potmaker and his assistant kneading it with their bare feet. The pots are moulded in an iron "flask" by means of a wooden "plug," and are slowly dried at the back of the stack, and the night before they are used gradually heated to a dull red heat, a process called annealing. Pot-making is a very important part of the manufacture of best cast steel. It is absolutely impossible to make good cast steel if the pots are defective. Each pot lasts a single day, and is used three times, containing severally about 50, 44 and 38 lbs. of steel each round. The object of lessening the weight of each successive charge is to bring the surface of the molten metal to a different place in the pot, because the "flux," or scum, which accumulates on the surface has a chemical action on the silica of the pot, which is consequently decomposed for some depth just at that point, and the pot is reduced in thickness.

The bar steel is first carefully selected of the exact temper required, all flushed or aired bars are rejected, and after it has been broken up into small pieces and carefully weighed, it is conveyed to the pot, which has already been placed in the melting hole, through an iron funnel called a charger. The lid is carefully adjusted, and the melting hole filled with coke. The degree of heat to which the furnace is allowed to go is care-

fully regulated by the "puller-out," who is technically said to "work" the holes, and who has perfect control over them by means of the two flues, into either of which he can insert a firebrick if required; a brick in the melting hole flue lessens the heat by lessening the draft; one in the cellar flue increases the heat by increasing the draft. The head melter periodically inspects the pots, and gives the final instructions to the puller-out, and decides the precise moment when the steel is dead melted, and the holes sufficiently burnt down to allow of its being "teemed" or poured into the mould with a fair chance of producing a sound ingot. When the "puller-out" has put on his "clothes," by which is meant a series of sacking wraps which envelop the arms and legs, and are soaked with water to protect him from the heat, he raises the pot with a pair of "pulling-out tongs," and lifts it from the hole to the floor of the furnace. The lid is instantly taken off with a pair of lid tongs, and the scum or flux is removed by a skimmer from the surface of the molten steel, which is then poured into a cast-iron mould formed of two halves tightly ringed and wedged together. The interior of the mould has been previously "reeked" or covered with a coat of coal-tar soot, to prevent the ingot from adhering to it. The melting of the higher qualities of steel is a process requiring the greatest skill, and one of the principal reasons why the trade has become to such a remarkable extent localized in Sheffield, is the importance to this branch of the trade of being able to select from a large class of more or less experienced workmen, the few exceptional men in whom sound judgment, technical skill, and steady habits are combined. The chances of accident in the melting of steel are many and various. Not only badly made pots, but badly annealed or badly worked pots, are sure to "run," and the steel to be deposited amongst the ashes, where it imbibes so much sulphur as to be practically of no value. Should a piece of coke accidentally find its way into the pot, the ingot will show a bright sparkling fracture—technically speaking it will be said to "stare"—and under the hammer will prove "hot short," and crumble to pieces. If the steel be not long enough in the fire, it will teem fiery and produce a honeycombed ingot, and the same result will follow if it be too hot when it is poured. If it remain too long in the fire it will teem "dead," "the fracture of the ingot will look scorched," and though exceptionally sound, it will be brittle if hard, and wanting in tensile strength if mild. If the molten steel be chilled before it is poured into the mould, which may be detected by the stream skimming over as it is teemed, the fracture of the ingot will appear dull in color, and full of small holes or honeycombs.

All ingots having a proportion of 1 per cent. or more of carbon, if properly melted with pipe, that is to say, the steel in the center of the ingot will settle down as it cools, leaving a hollow space in the middle at the top of the ingot to the depth of from 3 to 5 inches. When the ingot has become cold it must be topped, that is to say, the hollow part must be broken off, until the ingot shows a sound fracture, and before this fracture has had time to rust, the ingots must be carefully examined; the ingots which are not properly melted must be rejected, and the exact percentage of carbon which each ingot contains must be marked upon it. An experienced eye can judge of the percentage of carbon contained in an ingot to a wonderful nicety by the appearance of the fracture. Between 1 per cent. of carbon and 1½ per cent. every tenth per cent. is well marked, and an experienced hand will detect a difference between, for example, 1.3 and 1.35 per cent. In order to reduce the ingot of cast steel to the size and shape required by the consumer, it must be reheated, and, when hot enough, hammered or rolled to the dimensions ordered. Great care must be exercised in this process not to burn or overheat the steel: and, to prevent this, the half "cogged" bar must be continually turned round in the fire, and ground fireclay or sand and borax sprinkled upon it. In many cases it is necessary to give the surface of the bar, after it has been once drawn down under the hammer, a welding or "wash" heat, to close the small honeycombs which are scattered here and there on the surface of the ingot. It is a matter of great importance, especially with large ingots, that they should not be hammered until they are thoroughly heated or "soaked"

through, and it is of equal importance to all ingots that they should not lie too long "soaking" in the fire, especially in a dry fire, that is, one without blaze. The effect of hammering steel is to make it crystallize in very small crystals, a result which greatly improves its quality, but at the same time exposes it to the risk of various accidents in the process. The forging, tilting, and rolling of cast steel all require very experienced workmen, and a considerable outlay of expensive machinery. It is seldom that a workman attains exceptional skill in many departments, and great loss is sustained by too often changing faces or rolls, so that these processes cannot be satisfactorily or cheaply carried on upon a small scale, and this is one of the chief reasons why the crucible cast steel trade has to such a large extent become localized in a single town.

It might be supposed that when the best quality of iron had been selected, and the greatest care used in all the processes of manufacture—the converting, the melting, and the forging—the result must of necessity be good steel, and the troubles of the steel manufacturer would be over. But this is not the case by any means. So far from being over, the greatest difficulty has yet to be faced. The result may be good steel, but good steel only for certain purposes. There was a time, in the golden age of steel manufacturing, when steel was steel; and if it did not answer the purpose for which it was required, it was taken for granted that the fault lay with the workman. In some cases the manufacturer altered the percentage of carbon; but the "temper" of the steel was kept a profound secret from the consumer—in most cases, no doubt, because the manufacturer had very vague ideas on the subject himself. Chemical analysis was unknown in the trade; the despotic sway of the rule of thumb reigned supreme. Now it is customary for the manufacturer to take the customer into his confidence, and not only to inform him of the percentage of carbon which the steel contains, but also to give him the benefit of his opinion as to the purposes for which it is or is not suitable. Formerly, if the consumer discovered that chisel steel contained less carbon than tool steel, he owed his discovery entirely to his own wit. There can be no doubt that for many purposes a considerable latitude may be permitted, if the steel has the good fortune to fall into the hands of a clever workman who understands how to "humor" it, but next to quality—by which is meant percentage of phosphorus, sulphur, &c., combined with some other obscure points of crystallization—the most important thing is temper, or percentage of carbon. For some purposes, indeed, temper is of more importance than quality. Nothing is more common than for steel to be rejected as bad in quality, because it has been used for a purpose for which the temper was unsuitable. We may divide consumers of steel into three classes. First, those who use their own judgment of what percentage of carbon they require, and instruct the manufacturer to send them steel of a specified temper; second, those who leave the selection of the temper to the judgment of the manufacturer, and instruct him to send them steel for a specified purpose; and third, those who simply order steel of a specified size, leaving the manufacturer to guess for what purpose it is required. Fortunately, the size and shape generally furnish some clue to the purpose for which it is likely to be used. For example, oval steel is almost sure to be used for chisels, and small squares for turning tools, but $1\frac{1}{4}$ square may be used for a turning tool or a cold sett, or $1\frac{1}{4}$ round for a drill or a boiler cup, and the manufacturer has to puzzle his brain to discover whether the chances are in favor of its being used in the lathe room or in the blacksmith's shop. It cannot too often be reiterated of how much importance it is, when ordering steel, to state the purpose for which it is going to be used. Of course the number of tempers of steel is infinite, but the following is a list of the most useful:

Razor temper ($1\frac{1}{2}$ per cent. carbon).—This steel is so easily burnt by being over-heated that it can only be placed in the hands of a very skillful workman. When properly heated, it will do twice the work of ordinary tool steel for turning chilled rolls, &c.

Sawfile temper ($1\frac{3}{8}$ per cent. carbon).—This steel requires careful treatment; and although it will stand more fire than

razor-steel, should not be heated above a cherry-red.

Tool temper ($1\frac{1}{4}$ per cent, carbon.)—The most useful temper for turning tools, drills, and planing-machine tools in the hands of ordinary workmen. It is possible to weld cast steel of this temper, but only with the greatest care and skill.

Spindle temper ($1\frac{1}{8}$ per cent. carbon).—A very useful temper for circular cutters, very large turning tools, taps, screwing dies, &c. This temper requires considerable care in welding.

Chisel temper (1 per cent. carbon).—An extremely useful temper, combining as it does great toughness in the unhardened state, with the capacity of hardening at a low heat. It is consequently well adapted for tools when the unhardened part is required to stand the blow of a hammer without snipping, but where a hard cutting edge is required, such as cold chisels, hot setts, &c.

Sett temper ($\frac{7}{8}$ per cent. carbon).—This temper is adapted for tools where the chief punishment is on the unhardened part, such as cold setts, which have to stand the blows of a very heavy hammer.

Die temper ($\frac{3}{4}$ per cent. carbon).—The most suitable temper for tools where the surface only is required to be hard, and where the capacity to withstand great pressure is of importance, such as stamping or pressing dies, boiler cups, &c. Both the last two tempers may be easily welded by a mechanic accustomed to weld cast steel.

It is a somewhat remarkable fact that although steel is intermediate in chemical composition between wrought iron and cast iron, containing more carbon than the one and less than the other, its properties are quite different from either of them. It may be made to resemble either of them alternately, but it is principally used in a third condition, in its capacity to assume which the great value of steel consists. Annealed steel has nearly all the properties of lead, being very soft and malleable. Hardened steel has nearly all the properties of glass, being very hard and brittle. Tempered steel has most of the properties of whalebone, being hard but at the same time elastic. The chemical change which takes place during these processes has not yet been discovered. We might evolve a very pretty theory to account for it, by assuming that in the process of annealing some of the combined carbon was liberated, and existed in the steel in the form of free or uncombined carbon; but such a theory only explains part of the facts, and is not, I am afraid, borne out by the results of chemical analysis, so that we must fall back upon the mysterious and unknown laws of crystalization. The effect cannot be due simply to the increased density of the hardened steel caused by the contraction of the steel by sudden cooling. It is a remarkable fact that the specific gravity of hardened steel is less than that of unhardened steel. Steel, of course, expands with heat, and when it is allowed to cool slowly regains its original size; but if it be cooled suddenly, the only known way in which it can be hardened, although it contracts very much, it does not quite reach the small size of the unhardened state. However complicated the details of the manufacture of cast steel may be the complications involved in its subsequent use are still greater. It would be impossible to lay down exact rules for each of the thousand and one tools in which steel is used. The treatment of each tool in each process which it undergoes is an art that can only be learnt by practice, and can no more be taught in a book than the arts of skating, riding, or swimming. The utmost that can be done is to lay down certain general rules, which may explain to some extent, if they fail to teach, the most important details of manipulation. All steel may be regarded as involving a question of compromise. Each tool requires a certain degree of hardness; the problem is how to secure the maximum amount of toughness that is compatible with it. To secure this, the first step that must be taken in bringing the steel into the shape required is to heat the steel as little as may be before it is forged, and in the process of forging to hammer it as much as possible. The worst fault that can be committed is to heat the steel more than is necessary. When steel is heated it becomes coarse-grained; its silky texture is lost, and can only be restored by hammering or sudden cooling. If the temperature be raised above a certain point, the steel becomes what is technically called "burnt."

and the amount of hammering which it would require to restore its fine grain would reduce it to a size too small for the required tool, and the steel must be condemned as spoilt. Overheating in the fire is also the primary cause of cracking in the water. One of the principal reasons why a high quality of steel is required for certain purposes is, that it will suffer less injury by being heated to a greater degree, or by being heated and reheated a greater number of times, than inferior qualities of steel. In heating steel the happy medium must be attained between heating it too much or too little, and between letting it lie too long "soaking" in the fire and not "soaking" it through. Both the degree of temperature and the duration of the heat must be carefully watched. Some tools, such as circular cutters, files, &c., after they are forged into the shape required, must have teeth cut into them. Before this can be successfully accomplished a preliminary process has to be gone through. The process of hammering or forging the steel into the shape required has hardened it to such an extent as to make the cutting of teeth into it impossible or difficult, and it must consequently be annealed. This process consists in reheating the steel as carefully as before, and afterwards allowing it to cool as slowly as possible. Many tools are only required to be hardened on a small part of their surface, and it is important that the unhardened parts should possess the maximum amount of toughness, the minimum amount of brittleness that can be attained. The process of annealing, or slow-cooling, leaves the steel coarse-grained, gives it its maximum of ductility, and causes it, in fact, to approach in its properties those of lead.

The last process in the manufacture of articles made of steel, where the invaluable property which distinguishes steel from wrought iron or cast metal is revealed, is the double process of hardening and tempering, by which we suddenly change the steel from lead into glass, and afterwards gently change the glass into whalebone. In these as in all other processes which steel has to undergo, it has again to run the gauntlet of fire. It does so, however, at much greater risk than heretofore. The forging of the tool is finished; it has taken the final shape to which it was destined; and any injury which may be done to it by overheating is irrevocable, and can no longer be cured or mitigated by the hammer. It is necessary, therefore, to double and redouble the care bestowed upon the heating of the steel, lest the temperature be raised beyond the point necessary to secure the required hardness. The part of the steel required to be hardened must be heated through and heated evenly, but must on no account be overheated. The tool must be finished at one blow, the blow caused by the sudden contraction of the steel produced by its sudden cooling in the water, and if this blow be not sufficient to give to the steel a fine grain and a silky texture, if after the blow is given the fracture (were the tool broken in the hardened part) would show a coarse grain and dull color instead of a fine grain and glossy luster, the tool is spoiled, the labor bestowed upon it is thrown away, and it must be consigned to the limbo of "wasters." The special dangers to be avoided in hardening each kind of tool must be learned by experience. Some tools will warp, or "skeller," as we say in Yorkshire, if they are not plunged into the water in a certain way. Tools of one shape must cut the water like a knife; those of another shape must stab it like a dagger. Some tools must be hardened in a saturated solution of salt, the older the better; whilst others are best hardened under a stream of running water. Most tools have a tendency to water-crack if taken out of the water before they are absolutely cold. Where the edge of a tool only is hardened care should be taken to move it up and down in the water, so as continually to change the water level lest the tool should crack at the water level. Steel contracts in hardening, and contracts differently where it is cooled suddenly from the places where it is cooled slowly. If the hardened part joins the unhardened part too suddenly, the steel at the junction will be in a dangerous condition of tension, which predisposes it to crack, and it is wise to lessen the amount of tension by distributing it over as great an area as possible. In some tools, where the shape necessitates a great difference in the rapidity of the cooling of the various parts, it is often wise to drill holes in the thicker parts, where they will not inter-

fere with the use of the tool—holes which are made neither for use nor ornament, but solely with a view of equalizing the rapidity of the cooling of the various parts, so as to distribute the area of tension, and thus lessen the risk of cracking in hardening. So many causes may produce water-cracks, that it is often difficult to point out the precise cause in any given case. The most common cause is the overheating of the steel in one or other of the various processes through which it has to pass. A second cause may be found in the over-melting or too long boiling of the steel, causing it to part with too much of its occluded carbonic acid, a fault which may be attributed to the anxiety of the manufacturer to escape honeycombs in the ingot. A third cause may sometimes be discovered in the addition of too much manganese, added with the same motive. A fourth cause may, curiously enough, prove to be a deficiency of carbon, one of the most common causes of water-cracking in files; whilst in some cases too much carbon will produce the same effect. A fifth cause may be one which, as a steel manufacturer, I ought to mention in a whisper—the presence of phosphorus in the steel; but, after all, this may not be the fault of a too greedy manufacturer, who wants to make too much profit; it may possibly be the fault of a too stingy consumer, who will not pay a price sufficient to admit of a good quality of iron being used. There is nothing so dear as cheap steel. It must be more economical to put five shillings' worth of labor upon steel that costs a shilling, to produce a tool that will last a week, than to put the same value of labor upon steel that costs only ninepence, to produce a tool that will only last a day. The system adopted by some large consumers of buying best tool steel by tender, is one which in too many cases defeats the object for which it was instituted, and by lessening the price, and consequently deteriorating the quality, causes the steel bill to be apparently lessened at the cost of the labor bill, so that extravagance instead of economy is the result. In fact it is an illustration of the proverb about being "penny wise and pound foolish." Scores of firms in the steel trade habitually offer best cast steel at prices varying from forty to forty-five pounds a ton. The statement that the steel supplied is the best that can be made may be accurately described by an ugly little word of three letters, and the firms which make it are liable to be suspected of "voluntary inaccuracy."

The culminating point in the manufacture of tools made from steel, the final process which gives to them their most valuable properties—properties possessed by no other metallic substance—is that of tempering. The steel was originally lead; the process of hardening has turned it into glass; but we do not want glass—it is too brittle; we want whalebone. An unhardened knife would bend like wrought iron; a knife hardened only would break like cast metal. We want the elasticity of the whalebone. Our knife must spring like—like what?—like *steel.* To attain this quality it must be tempered. If a piece of hardened steel be heated slightly and then allowed to cool, it becomes tempered. It suddenly changes from glass to whalebone, and in the process of changing its nature it fortunately changes its color, so that the workman can judge by the color which it has assumed the extent of the elasticity which it has acquired, and can then give to each tool the particular degree of temper which is most adapted to its special purpose. The various colors through which tempered steel successively passes are as follows—straw, gold, chocolate, purple, violet and blue. Of course in passing from one color to another, the steel passes through the intermediate colors. It really passes through an infinite series of colors, of which the six above mentioned are arbitrarily selected as convenient stages. It must be borne in mind that the elasticity of tempered steel is acquired at the expense of its hardness. It is supposed that the maximum of elasticity and hardness combined is obtained by tempering down to a straw color. In tempering steel, regard must be had to the quality most essential in the special tool to be tempered. For example, a turning tool is required to be very hard, and is generally taken hot enough out of the water to temper itself down to a degree so slight that no perceptible color is apparent; whilst a spring is required to be very elastic, and may be tempered down to a blue. Hardening in oil is a mode of treating

steel which is of special value for certain tools, and appears, to a certain extent, to attain by one process the change from lead into whalebone without the passage through the intermediate glass stage. It is unfortunately not yet possible to give any scientific explanation of the change which takes place in the hardening and tempering of steel. All that chemists can yet do is to mystify their readers by writing unintelligibly about molecular rearrangement and crystalline transformation.

In speaking of the various foreign substances which are found in cast steel, I have confined myself, for the most part, to those which are supposed to be injurious to its quality; but before I close my paper, a word or two must be said upon the various materials which are added to cast steel with the intention of improving it. If the steel manufacturers of Sheffield are not doctors of chemistry, they most of them practice as quacks. It has ever been a darling dream of the Sheffield steel melter to discover some substance—some philosopher's stone—which will transmute common cast steel into best cast steel. The various substances used in the melting of cast steel, and supposed to have a chemical effect upon the material melted, are known by the technical name of "physic." The most universally used of these is peroxide of manganese, mixed with a little ground charcoal. Common salt, rock salt, salammoniac, chromate of potash, prussiate of potash, and even ground fluor spar and broken glass, form ingredients of the physic used by some steel melters. Manganese, either in the form of spiegeleisen, or of ferro-manganese, is also largely used, and has a definite effect upon the steel, it prevents, to a large extent, the formation of honeycombs in the ingot, and increases the welding capacity of the steel; it gives the steel a greater tenacity when hot, so that it may be heated to a greater heat without cracking under the blow of the hammer or the tension of the rolls; but it must be very cautiously used, as it undoubtedly increases the brittleness of the steel, and its tendency to water-crack, if it be added in the melting pot, instead of being previously suffused through the iron. Silicon is even more dangerous; it causes the steel to crystallize in smaller crystals; it materially assists its capacity to receive a high polish; it increases its soundness, but makes it more brittle. Wolfram, or tungsten, added in the form of a metallic alloy, is used to a considerable extent in the manufacture of a special steel, sometimes called Musbet steel, which is frequently made so hard that it does not require to be hardened. It is used principally for turning tools, which, in consequence of the temper of the steel not being liable to injury by heat, can be driven at a higher speed than usual. Special steel of this kind is the finest grained that can be produced, but is so brittle that it can only be used by exceptionally skilled workmen. Chromium is sometimes used instead of wolfram, and it is said that titanium is also employed, but I am not aware that any of the latter metal has yet been detected in steel by chemical analysis. A special steel for taps, called mild-centered cast steel, is made by converting a cogged ingot of mild cast steel so that the additional carbon only penetrates a short distance. These bars are afterwards hammered or rolled down to the size required, and have the advantage of possessing a hard surface without losing the toughness of the mild center.

It is much to be regretted that no easy method of testing cast steel has been invented. The amount of breaking strain, and the extent of the contractions of the area of fracture, give valuable information respecting iron or steel which is not hardened, and is not required to be used in a hardened state, but for hardened and tempered steel they are practically useless. It is very difficult to harden and temper two pieces of steel to exactly the same degree. A single test is of comparatively small value, as a second-rate quality of steel may stand very well the first time that it is hardened, but deteriorates much more rapidly every time it is rehardened than is the case with steel of a high quality. Nor is the breaking strain a fair test of the quality of cast steel. For many tools the capacity to withstand a high amount of breaking strain, slowly applied, is not so much required as its capacity to withstand a sudden shock. The appearance of the fracture of cast steel is also very illusory. The fineness of the grain and the silkiness of the gloss are very capti-

vating to the eye, but can be produced by hammering the bar until it is almost cold.

The consumer of steel may be enraptured, if he be of a poetical turn of mind, by the superb fracture of a bar of steel, reminding him of a picture by Ruskin of the aiguille structure of the higher Alps. But, after all, this is only a dodge, depending upon the inclination of the axis of the revolving hammer to the plane of the anvil. The practical consumer of steel must descend from the heights of art and science and take refuge in the commonplace of the rule of thumb, and buy the steel which he finds by experience to be full of "nature" and "body." If I have been successful in my attempt to explain the art and mystery of crucible cast steel making, you will have understood that the converting, melting and forging of steel are three arts, each of which requires as much dexterity as the arts of skating, riding or swimming. To arrive at perfection in these arts is difficult to those who do not inherit from skilled ancestors the facility to learn them; hence the trade has become localized in a few centers, of which Sheffield is the oldest and by far the most important. The arts of forging, hardening and tempering, which are necessary for the further manipulation of the steel after it leaves the hands of the manufacturer in Sheffield require equal dexterity, so that the art of steelmaking, if not mysterious, is very complicated. The real mystery lies in the chemical explanation of the effects produced, and when chemists have explained the phenomena of hardening and tempering steel, they may possibly discover why cast steel made from Dannemora iron is superior to the imitations of it. At present I presume that the candid chemist must admit that there are more things in best crucible cast steel than are dreamt of in his philosophy.

THE CAUSES AND REMEDIES OF CORROSION IN MARINE BOILERS.

By J. HARRY HALLETT.

From "Iron."

Marine engineers are all striving in various ways to attain increased economy of fuel in steamers. Among other means of doing so, triple-expansion engines of high initial pressure are being introduced, which appear to be gaining much favor, and will no doubt in time supersede the ordinary two-cylinder type. The increased pressure of steam evidently renders it necessary to be still more guarded than hitherto as to the deterioration of boilers. Steel boilers are now in very general use, and there can be no doubt as to their efficiency; but the writer's experience is that they are equally liable with iron boilers to corrosive influences. On careful scrutiny he has found in steel plates severe corrosion concealed by a very slight scale, upon the removal of which the plate has proved to be covered with a black substance, probably a black oxide of iron. In many cases a casual inspection may fail to detect this. Internal corrosion is well known to be most erratic in its action; it attacks the metal in different parts of the boiler, in different ways, and from various causes. The principal sources of corrosion, however, may be discussed under the two heads of defective design and defective management: which is equivalent to saying that an ordinary marine boiler will hardly be subject to corrosion at all, if well designed and well managed.

Design.—The most frequent fault of design which bears upon corrosion is the want of sufficient space for allowing a thorough examination to be made of every part of the boiler. The tubes are often placed so far out in the wings that it is impossible to get down to look at the sides of the furnaces, or so close to the furnace crowns that there is no room to get over these. It would be preferable to allow at least nine inches between each furnace crown and the bottom row of

tubes, especially as this row is not useful as heating surface when placed so close down to the crown. The manholes are often inconveniently placed and made too small, which always affords an excuse for want of proper attention on the part of the men in charge. Manholes should always be fitted in the wings if the size of boiler will allow. There can be no doubt that the best way to prolong the life of a boiler is to watch it carefully and constantly, so as to note the commencement of deterioration and take steps to check it. In any part which cannot be seen, it is impossible to know what is going on. Another fault of design, which easily escapes notice until too late, is the pitching of the steam-space stays, so that one or perhaps several of them come over a space, instead of over a tube, thus rendering the effective use of the scaling tool very difficult, or even impossible in that particular vertical space. With the object of securing the conventional 20 square feet of heating surface per horse-power, the tubes are sometimes too closely pitched, which causes bad circulation, besides rendering the spaces liable to become soon choked with scale. The tubes should never be less than $1\frac{1}{4}$ inch apart, both vertically and horizontally.

Management.—The first point to be looked to in the management of a boiler is the circulation. In an ordinary multibular marine boiler the circulation takes place by the water ascending from the furnace crowns, and from the sides, backs, and fronts of the combustion chambers, and descending at the wings; the tubes do, of course, somewhat obstruct the upward current. There can be no doubt that the coolest places in the boiler are those where the circulation is most defective, as is naturally the case below the level of the fire-bars. The water in this part of the boiler always contains the greatest percentage of solid matter, and here the greatest deterioration may, therefore, be expected to be found. Double-ended boilers are not only subject to the same corrosive action as single-ended ones, but being longer they are also more prone to suffer from racking strains, due to the difference of temperature between their upper and lower parts. One method of reducing this difference as far as possible, is to fit the internal feed-pipe so that it is led along on a level with the upper tubes, so as first to warm the water inside it, and is thence carried down so as to discharge the warmed water in a horizontal direction at the bottom of the boiler. The scum pipe should be fitted with a pan, shaped like an inverted saucer, and placed just above the level of the water for the scum to collect under it; and it should always be blown off upon raising steam, and also about once a day when under weigh. The blow-off cock should either be attached at the bottom of the boiler, or else an internal pipe should be fitted to it, reaching down to the very bottom. Salt is not deposited until the density of the water exceeds 4-32ds by the salinometer, that is, until there is more than 4 lbs. of salt in 32 lbs. of water; beyond this proportion the deposition of salt then begins upon the furnace crowns, &c. It is recommended that the opportunities occurring from time to time by the engines being stopped should be taken advantage of for pumping up the boiler to the top of the gauge glass, and then blowing it down to the bottom of the glass. This, repeated about twice or thrice on each occasion, will work wonders. The great usefulness of this plan arises from the fact that while the engines are stopped there is little or no steam being made, and therefore no solid matter is being deposited from the water; so that the extra feed-water pumped in at that time does much more to freshen the boiler than it would if the engines were at work. When in charge of the engines of a steamer on a voyage from England to Rangoon, calling at several ports on the way, and thence to Venice, the writer kept water in the boilers continuously during the whole round; that is to say the boilers were never entirely run out and refilled, but were blown down from time to time as above described. They were under steam about seventy-two days, and upon being opened out at the end of that time had only a slight scale upon them of uniform thickness, and no indication of pitting or corrosion.

The mode of treatment adopted by the writer for new boilers is to have them well washed out before filling, then to run them up, and when they are filled with water up to the normal height, to throw into each through the top manhole about a bucketful of common soda. When steam is raised to about 30 lbs. per square

inch, blow out a little through the scum cock. Before adding any more water, start the feed donkey, and let it deliver for sometime over the side of the ship, so as to get rid of any dirt, &c., in the pump; this is a very useful precaution to observe whenever the feed donkey is employed. After starting the main engines, let them run at first with the feed water overflowing from the hot well into the bilges; this will clear the condenser. When under weigh, it is advisable to use the blow-down cocks sparingly. The appearance of the water in the gauge glass shows at a glance the state of the water in the boiler; if the glass is at all dirty inside, that is proof positive of the water not being clean enough; and this can be cured by the use of the scum cock. In a double-ended boiler a scum pipe should be fitted at each end. The scum pipes are sometimes so fitted that their position can be altered to suit the trim of the ship, which is a point of far more importance than is generally imagined. After a run, when steam is finished with, the water should be blown out from the bottom and the boilers then kept thoroughly dry. Before refilling they should be carefully swept down inside, and washed out. There is no doubt that one of the most active causes of deterioration in boilers is the want of proper care in their treatment. Cases have come under the author's notice of boilers being blown down as far only as the level of the bottom manholes, and refilled, without care being taken to draw the water out of the bottoms. This process having been frequently repeated, the water at the bottoms became so impregnated that the heads of the rivets and the lower half of the compensating rings round the manholes were corroded away, while the other parts of the boilers were in good condition. Many good boilers are ruined through careless management, and the makers are wrongly charged with allowing their work to come from the shop not properly finished. Another example, out of numerous cases met with, is that of a pair of boilers which were fitted some little time ago with hydro-kineters, or internal steam-jet nozzles for stimulating the circulation of the water in the cooler places below the furnace flues. Upon a recent examination the valves of these appliances were found to be hard and fast, in consequence of carelessness in supervision. Another great evil is raising steam too quickly, and blowing out under too great a pressure, which cannot be too strongly condemned. Corrosion in the upper parts of the boiler is principally caused by the introduction of oil, tallow, and other greasy substances from the engines. In all the steamers with which the writer is connected he has discarded the use of all oil or other lubricant in the cylinders, with the most satisfactory results.

Various remedies have been suggested for preventing corrosion; among others, air-extractors and circulating tubes. Zinc has been tried, both cast and rolled, and some engineers report favorably on its use; but to make it effective, very large quantities must be used, as it so quickly oxidizes, and thus loses its protective qualities. The electrogen of Mr. Hannay's invention, which is rapidly gaining favor, is a very simple little appliance, and, as far as the writer has experimented with it, is very effective. The principle upon which it works is the setting up of a small galvanic battery in the boiler, by mans of a ball of zinc cast upon a copper bar, and then hammered, to make it more impervious to the action of the water; on each end of the copper bar a wire is soldered, and the two wires are again soldered to different parts of the boiler, so as to obtain metallic contact. Boilers which had shown a tendency to corrosion looked quite healthy in a very short time after these appliances had been fitted to them. Marine boilers are not troubled with much external corrosion, especially modern boilers, because much more care is now taken in fitting them into the ships than was formerly the case. They are now properly coated, and are not fitted too close down to the bottom of the ship, plenty of room being allowed for access to the seams. But that all the mischief to be contended with is not confined to the waterside of the boiler is shown by the following incident. Some four and a half years ago the writer was called in to survey a boiler that had exploded and killed the chief engineer and firemen. Upon examination it was found that the bridges had been built up close to the backs of the combustion chambers; the dirt, &c., had been allowed to accumulate for some time, and corrosion had been going on upon both sides of the plate without be-

ing noticed. After the accident, when all had been cleared away, the iron was found to have oxidized so much that in some parts it was barely 1-16th of an inch thick; hence the explosion. The backs had been so built up for the express purpose of economising fuel; but experience goes to prove that this is a fallacy, and many cases could be mentioned where similar bridges have been taken out without making any difference in consumption of fuel, except that, if anything, the economy had been in favor of their absence. There is nothing like cleanliness to prolong the life of a boiler. When a vessel is to be laid up, a good plan is to pump the boiler full up to the very top of the dome, and keep it so until it is again required. Another method of preserving a boiler not in use is to empty it and clean it thoroughly, then close all the manhole doors except one at the bottom, put in a small stove full of burning coke, and close up the bottom door quickly. The object of both these methods is, of course, to exclude air as thoroughly as possible.

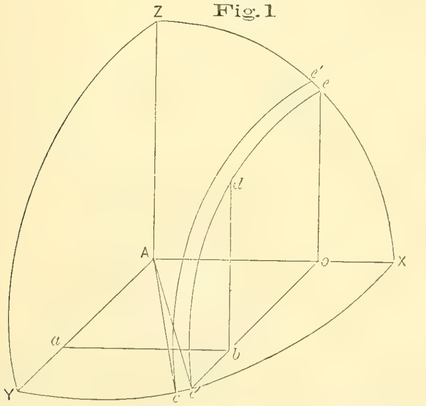
GENERAL DISCUSSION OF WIND PRESSURE UPON SPHERICAL, CYLINDRICAL, AND CONICAL SURFACES.

By P. H. PHILBRICK.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

Let XYZA represent one fourth of the windward half of a spherical dome; XA the direction of the wind, inclined to the horizon at angle a; cde and $c'e'$ two arcs near together in planes parallel to YAZ, and O the center of cde.

Fig. 1



$OAc=i$ $cAc'=di$, $r=$ radius of the dome.

Let P equal the pressure upon a unit of plane surface normal to the direction of the wind; N = the normal pressure upon any surface; X, Y, Z, the x, y and z components of the pressure.

We have, $co=r\ \sin.\ i$, $cde=\frac{\pi}{2}\ r\ \sin.\ i$, $cc'=rdi$;

∴ the area of the band

$$cde\ c'e'=\frac{\pi}{2}r^2\ \sin.\ i\ di. \quad (1)$$

According to Duchemin (see "Annals of Mathematics," vol. 1, No. 2, p. 47) the pressure upon a unit area of surface is $\frac{P}{1+\frac{1}{2}\tan.^2 i}$, i being the angle of incidence.

Hence the pressure on the band is

$$dN=\frac{P}{1+\frac{1}{2}\tan.^2 i}\cdot\frac{\pi}{2}r^2\ \sin.\ i\,di=$$

$$=P\pi r^2\frac{\sin.\ i\,di}{2+\tan.^2 i} \quad . \quad . \quad (2)$$

$$=P\pi r^2\frac{\cos.^2 i\ \sin.\ i\,di}{1+\cos.^2 i}=$$

$$P\pi r^2\left(\frac{d\ \cos.\ i}{1+\cos.^2 i}-d\ \cos.\ i\right) \quad (3)$$

$$\therefore\ N=P\pi r^2\int\left(\frac{d\ \cos.\ i}{1+\cos.^2 i}-d\ \cos.\ i\right)-$$

$$=P\pi r^2\left\{\tan.^{-1}\cos.\ i-\cos.\ i\right\}_0^{\frac{\pi}{2}} \quad . \quad (4)$$

$$=P\pi r^2\left(1-\frac{\pi}{4}\right)=.4292\,P\times\tfrac{1}{2}\pi r^2=$$

$$=.6742Pr^2. \quad . \quad . \quad (5)$$

On the dome the pressure is

$$4\,N=.4292\,P\times 2\pi r^2=1.3484\,Pr^2. \quad . \quad (6)$$

The average normal pressure is, therefore equal to $.4292\ P=\left(2-\frac{\pi}{2}\right)P$.

To find X. We have, $dX = dN \cos. i$; $\therefore$ from (4),

$$X = P\pi r^2 \int \left(\frac{\cos. i d \cos. i}{1+\cos.^2 i} - \cos. i\, d \cos. i \right)$$

$$= \tfrac{1}{2} P\pi r^2 \left\{ \log.(1+\cos.^2 i) - \cos.^2 i \right\}_{0}^{\frac{\pi}{2}} =$$

$$= \tfrac{1}{2} P\pi r^2 \,(1-\log. 2) = .6136$$

$$P \times \tfrac{1}{4}\pi r^2 = .4821\, Pr^2 \quad . \quad . \quad (7)$$

For the whole wind pressure

$$4X = .6136\ P \times \pi r^2 = 1.9284\ Pr^2 \quad . \quad . \quad (8)$$

Hence the X component of the pressure is equivalent to a pressure of .6136 P on each unit of the meridian plane YAZ.

The horizontal shearing strain between the dome and its supports, which is equal to the transverse shearing strain of the supports, is evidently $= 4X \cos. a$.

The moment of the wind pressure about the foot of the supports is equal to $4Xh \cos. a$, h being the height of the supports.

TO FIND THE COMPONENT Z.

The pressure on the band being constant the Z component of that pressure will be equal to the pressure multiplied by the length of the average ordinate (z say), divided by r. This ordinate is equal to the distance of the center of gravity of the quadrant cde from co.

Now, $z = \frac{2}{\pi} Oe = \frac{2}{\pi} r \sin. i$, $\frac{z}{r} = \frac{2}{\pi} \sin. i$.

Hence, by (3), $Z = 2Pr^2 \int \frac{\cos.^2 i \sin.^2 i\, di}{1+\cos.^2 i}$

$$= 2\, Pr^2 \int \frac{\sin.^2 i - \sin.^4 i}{1+\cos.^2 i} di. \quad (9)$$

$= 2\, Pr^2 \int \left(\sin.^2 i + 1 - \frac{2}{2-\sin.^2 i} \right) di$, by partial fractions.

$$= 2Pr^2 \left\{ \int (\sin.^2 i + 1)\, di - \int \frac{\frac{1}{2}\sqrt{2} di\, i}{\sqrt{2}+\sin. i} - \int \frac{\frac{1}{2}\sqrt{2} di}{\sqrt{2}-\sin. i} \right\} \text{ similarly.} \quad (10)$$

Now, $\int \frac{di}{\sqrt{2}+\sin. i} = \frac{2}{(2-1)^{\frac{1}{2}}} \tan.^{-1} \left\{ \frac{\sqrt{2}}{(2-1)^{\frac{1}{2}}} \left(\tan. \frac{i}{2} + \frac{1}{\sqrt{2}} \right) \right\} = 2 \tan.^{-1} \left\{ \sqrt{2} \left(\tan. \frac{i}{2} + \frac{1}{\sqrt{2}} \right) \right\}$

Similarly, $\int \frac{di}{\sqrt{2}-\sin. i} = 2 \tan.^{-1} \left\{ \sqrt{2} \left(\tan. \frac{i}{2} - \frac{1}{\sqrt{2}} \right) \right\}$

$$\therefore Z = 2Pr^2 \left[\frac{i - \sin. i \cos. i}{2} + i - \sqrt{2} \tan^{-1} \left\{ \sqrt{2} \left(\tan. \frac{i}{2} + \frac{1}{\sqrt{2}} \right) \right\} - \sqrt{2} \tan.^{-1} \left\{ \sqrt{2} \left(\tan. \frac{i}{2} - \frac{1}{\sqrt{2}} \right) \right\} \right]_{0}^{\frac{\pi}{2}}$$

$$= 2\, Pr^2 \left\{ \frac{3\pi}{4} - \sqrt{2} \tan.^{-1} \left(\sqrt{2}+1 \right) - \sqrt{2} \tan.^{-1} \left(\sqrt{2}-1 \right) \right\} = 2Pr^2 \left(\frac{3\pi}{4} - 2\sqrt{2} \tan.^{-1} 1 \right)$$

$$= 2\, Pr^2 \left(\frac{3\pi}{4} - \sqrt{2}.\frac{\pi}{2} \right) = \tfrac{1}{2} P\pi r^2 (3 - 2\sqrt{2})$$

$$= .3432\ P \times \tfrac{1}{4}\pi r^2 = .2695\ Pr^2. \quad (11)$$

The Z components of the pressure, above and below the plane XAY, are each equal to $2Z = .5391\ Pr^2$. . . . (12)

Similarly the Y components on either side of the plane XAZ are each equal to $2Y = .5391\ Pr^2$. . . . . (12)

The wind tends, therefore, to compress and distort the dome laterally and vertically, but not in the direction of the wind.

For a hemispherical dome, with the wind horizontal, we have from equations (5), (7) and (11),

$$2N = .4292\ P\pi r^2 \quad . \quad . \quad (13)$$
$$2X = .6136\ P\tfrac{1}{2}\pi r^2 \quad . \quad . \quad (14)$$
$$2Z = .3432\ P\tfrac{1}{2}\pi r^2 \quad . \quad . \quad (15)$$
$$Y = .3432\ P\tfrac{1}{4}\pi r^2 \quad . \quad . \quad (16)$$

In this case the additional *load* due to the wind pressure is, $.3432\ P\frac{1}{2}\pi r^2$, given by (15).

TO FIND THE POINT OF APPLICATION OF X.

The moment of dX about A is equal to dX multiplied by the distance of the center of gravity of cde from cO.

$\therefore dm = dX.\frac{2}{\pi} cO = dX \frac{2}{\pi} r \sin. i = \frac{2}{\pi} r \cos. i \sin. i\, dN.$

Hence, by (3) we have, $M=2\,Pr^3$

$$\int\frac{\sin.^2 i\cos.^3 i\,di}{1+\cos.^2 i} \quad . \quad (17)$$

Now $\int\frac{\sin.^2 i\cos.^3 i\,di}{1+\cos.^2 i}=\int\cos.i$

$$\left(\frac{2\cos.^2 i}{1+\cos.^2 i}-\cos.^2 i\right)di=$$

$$=\int\left(2\cos.i-\cos.^3 i-\frac{2\cos.i}{1+\cos.^2 i}\right)di$$

$$=\int(2\cos.i-\cos.^3 i)\,di-2$$

$$\int\frac{d\sin.i}{2-\sin.^2 i} \quad . \quad . \quad . \quad (18)$$

$$=\left\{2\sin.i-\frac{\sin.i\cos.^2 i}{3}-\tfrac{2}{3}\sin.i+\frac{1}{\sqrt{2}}\right.$$

$$[\log.(\sqrt{2}-\sin.i)-$$

$$\left.[\log.(\sqrt{2}+\sin.i)]\right\}_0^{\frac{\pi}{2}} \quad . \quad (19)$$

$$=\frac{4}{3}-\frac{1}{\sqrt{2}}\log.\frac{\sqrt{2}+1}{\sqrt{2}-1}=\frac{4}{3}-\frac{1}{\sqrt{2}}$$

$$\log.(3+2\sqrt{2})=.0868$$

$$\therefore\ M=.1736Pr^3 \quad . \quad . \quad . \quad . \quad (20)$$

Now $\frac{M}{X}=\frac{.1736Pr^3}{.4821Pr^2}=.3601r=\overline{Z} \quad . \quad (21)$

Since $.3601=\overset{-1}{\sin.}\ 21°6'$, the point is 21°6' from X on the arc XZ.

In a similar manner we have for Z, $dM'=dZr\cos.i$, which with (9) gives,

$M'=2\,Pr^3\int\frac{\cos.^3 i\sin.^2 i\,di}{1+\cos.^2 i}$ which is the same as (17).

Hence $M'=M=.1736\,Pr^3 \quad . \quad . \quad (22)$

This follows, indeed, from elementary principles; for, since the pressure on the dome is normal to the surface, the total moment about A is equal to zero; or the moment of X is equal to the moment of Z.

Now $\frac{M'}{Z}=\frac{.1736\,Pr^3}{.2695\,Pr^2}=.6440\,r \quad . \quad (23)$

The point is therefore 40°5′27″ from Z on the arc ZX.

Dividing (11) by (7) gives,

$\frac{.2695}{.4821}=.55901=\tan.\ 29°12'20''$, the angle made by the resultant wind pressure with the horizon.

The moments of X and Z about the center of the base of the dome being equal, it follows that the excess of the moment of X over that of Z about the foot of the supports, is equal to X*h*, *h* being the height of the supports. This is the moment of the force that inclines the dome to the leeward.

Since the Y and Z components of the pressure on the part of the dome shown in the figures are equal, the resultant R of the normal pressure is,

$$R=(X^2+2Z^2)^{\frac{1}{2}}=2Pr^2\,[(.4821)^2+2\,(.2695)^2]^{\frac{1}{2}}=.6145\,Pr^2 \quad . \quad . \quad (24)$$

Again, since the sum of the Y components on the whole dome is equal to zero, we have for the resultant of the whole normal pressure,

$$R=[(2X)^2+(2Z)^2]^{\frac{1}{2}}=Pr^2[(.9642)^2+(.5391)^2]^{\frac{1}{2}}=1.1047\,Pr^2 \quad . \quad . \quad (25)$$

The angle between the two partial resultants is given by,

$$\cos.\theta=\frac{R_1^2-2R^2}{2R^2}=\frac{X^2}{X^2\times 2Z^2}=.6154.$$

$\therefore\ \theta=52°1'$. The partial resultants therefore, make an angle of 26°30″ with the plane XZ.

The pressure on the plane XZ is, therefore, R sin. 26°30″=.6145 $PR^2\times.4385=.2695\,PR^2$, which is the pressure in the direction YA . . . . (26)

This agrees with (11).

Fig. 2

Let ABCD represent a cylinder with

the axis vertical; r=radius, l=length. Let K O be the direction of the wind, and P any point on the surface.

Let KOB$=a$, BOP$=i$ and KOP$=\theta$.

Now cos. KOP=cos. KOB cos. BOP; or $\cos\theta=\cos. a \cos. i$.

Hence,

$$\frac{1}{1+\frac{1}{2}\tan.^2\theta}=\frac{2\cos.^2\theta}{2\cos.^2\theta+\sin.^2\theta}$$

$$=2\frac{\cos.^2 a\cos.^2 i}{1+\cos.^2 a\cos.^2 i}$$

$$=2\left(1-\frac{1}{1+\cos.^2 a\cos.^2 i}\right)$$

$$=2\left(1-\frac{1}{\sin.^2 i+(1+\cos.^2 a)\cos^2 i}\right)$$

The area of an elementary strip adjacent to the element PP′ is equal to $rldi$.

Hence the normal pressure

$$=2N=2rPl$$

$$\int\left(di-\frac{di}{\sin^2 i+(1+\cos.^2 a)\cos^2 i}\right)_{o}^{\frac{\pi}{2}}\times 2$$

$$=4r\,Pl\left\{i-\frac{1}{(1+\cos.^2 a)^{\frac{1}{2}}}\tan.^{-1}\right.$$

$$\left.\frac{1}{(1+\cos.^2 a)^{\frac{1}{2}}}\tan. i\right\}_{o}^{\frac{\pi}{2}}$$

$$=4r\,Pl\left(\frac{\pi}{2}-\frac{1}{(1+\cos.^2 a)^{\frac{1}{2}}}\cdot\frac{\pi}{2}\right)$$

$$=\pi r\,Pl\left(2-\frac{2}{(1+\cos.^2 a)^{\frac{1}{2}}}\right). \quad (27)$$

If $a=o$, $2N=\pi r\,Pl\,(2-\sqrt{2})=$
$$=.5858\,P\pi rl \quad . \quad . \quad (28)$$

The average normal pressure is, therefore, .5858 on each unit.

The pressure in the direction BO is, evidently

$$2H=2Prl\int\left(\cos. i\,di-\right.$$

$$\left.-\frac{\cos. i\,di}{\sin^2 i+(1+\cos.^2 a)\cos^2 i}\right)_{o}^{\frac{\pi}{2}}\times 2$$

$$=4Prl\int\left(d\sin. i-\frac{1}{\cos.^2 a}\cdot\right.$$

$$\left.\frac{d\sin. i}{\frac{1+\cos.^2 a}{\cos.^2 a}-\sin.^2 i}\right)$$

$$=4Prl\left(\sin. i-\frac{1}{2\cos. a\,(1+\cos.^2 a)^{\frac{1}{2}}}\right.$$

$$\left.\log.\frac{(1+\cos.^2 a)^{\frac{1}{2}}+\cos. a\sin. i}{(1+\cos.^2 a)^{\frac{1}{2}}-\cos. a\sin. i}\right)_{o}^{\frac{\pi}{2}}$$

$$=4Prl\left(1-\frac{1}{2\cos. a(1+\cos.^2 a)^{\frac{1}{2}}}\log.\right.$$

$$\left.\frac{(1+\cos.^2 a)^{\frac{1}{2}}+\cos. a}{(1+\cos.^2 a)^{\frac{1}{2}}-\cos. a}\right) \quad . \quad . \quad (29)$$

If $a=o$, $2H=4\,Prl$

$$\left(1-\frac{1}{2\sqrt{2}}\log.\frac{\sqrt{2}+1}{\sqrt{2}-1}\right)=.7536P\times 2rl \; (30)$$

This is equivalent to .7536 P on each unit of the meridian plane.

The lateral pressure, normal to the plane ABCD, is evidently,

$$Y=2\,Prl\int\left(\sin. i\,di-\frac{\sin. di}{1+\sin^2 a\cos.^2 i}\right.$$

$$=2\,Prl\int\left(\sin. i\,di-\frac{1}{\cos.^2 a}\cdot\right.$$

$$\left.\frac{\sin. i\,di}{\frac{1}{\cos.^2 a}+\cos.^2 i}\right)$$

$$=2\,Prl\left\{-\cos. i-\frac{1}{\cos. a}\right.$$

$$\left.\tan.^{-1}\cos. a\cos. i\right\}_{o}^{\frac{\pi}{2}} \quad . \quad . \quad (31)$$

$$=2\,Prl\left(1-\frac{1}{\cos. a}\tan.^{-1}\cos. a\right) \quad . \quad (32)$$

If $a=o$, $Y=Prl\left(2-\frac{\pi}{2}\right)=.4292\,Prl.$ (33)

This is equivalent to a pressure of .4292 P on each unit of the plane OBD.

The shearing strain is given by (30), and is, H=1.5072 Prl.

The moment of H about the foot of the supports is H $(\frac{1}{2}r+h)$, h being the height of the supports.

If the axis of the cylinder is horizontal, N and H are given as before, and Z, which is the same as Y in the preceding case, is given, of course, by equations (32) and (33.)

Let β= the angle between the direction of the wind and the horizon. This is equal to the angle between H and the horizon, or Z and the vertical plane through the axis of the cylinder.

The moment of H about the foot of the supports is therefore, H $(\frac{1}{2}r+h)\cos.\beta$.

Let us consider a right cone standing upon its base.

Let $2r$=the vertical angle of the cone.

Let a=the angle between the direction of the wind and the normal to the axis, the angle being considered positive downward.

$a+v$=the angle between the direction of the wind and the normal to the element of the cone on the windward side.

Substituting this for a, and the convex surface of the cone for that of the cylinder in eqs. (27), (29) and (32), we have,

$$2N=\tfrac{1}{2}P\pi rl\left(2-\frac{2}{(1+\cos.^2(a+v))^{1/2}}\right) \quad (34)$$

$$2H=2Prl$$

$$\left(1-\frac{1}{2\cos.(a+v)[1+\cos.^2(a+v)]^{1/2}}\right.$$

$$\left.\log.\frac{(1+\cos.^2(a+v))^{1/2}+\cos.(a+v)}{(1+\cos.^2(a+v))^{1/2}-\cos.(a+v)}\right). \quad (35)$$

$$Y=Prl$$

$$\left(1-\frac{1}{\cos.(a+v)}\tan.^{-1}\cos.(a+v)\right). \quad (36)$$

If the wind is horizontal, $a=o$, and the above equations become,

$$2N=\tfrac{1}{2}Prl\left(2-\frac{2}{(1+\cos.^2v)^{1/2}}\right) \quad . \quad . \quad . \quad (37)$$

$$2H=2\,Prl\left(1-\frac{1}{\cos.v\,(1+\cos.^2v)^{1/2}}\log.\right.$$

$$\left.\frac{(1+\cos.^2v)^{1/2}+\cos.r}{(1+\cos.^2v)^{1/2}-\cos.r}\right) \quad . \quad (38)$$

$$Y=\left(1-\frac{1}{\cos.\ v}\tan.^{-1}\cos.\ v\right) \quad . \quad . \quad . \quad (39)$$

If $a=-v$, the wind is normal to the element of the cone on the windward side, and equations (34), (35) and (36), become,

$$2N=\tfrac{1}{2}\pi rPl\,(2-\sqrt{2}) \quad . \quad . \quad . \quad . \quad (40)$$

$$2H=2Prl\left(1-\frac{1}{2\sqrt{2}}\log.\frac{\sqrt{2}+1}{\sqrt{2}-1}\right). \quad (41)$$

$$Y=\tfrac{1}{2}\,Prl\left(2-\frac{\pi}{2}\right) \quad . \quad . \quad . \quad . \quad . \quad (42)$$

These equations are just one half of equations (28), (30), and (33), as they ought to be, since the surface of the cone is one-half that of the cylinder.

The moment of H about the foot of the supports is evidently

$$M=H\,(\tfrac{1}{3}\,l+h)\cos.\,a \quad . \quad . \quad . \quad (43)$$

Which becomes, $M'=H\,(\frac{1}{3}\,l+h)$ when the wind is horizontal . . . . . . (44)

If the apex is downward, equations (34). . . .(39) apply by putting $-v$ for v. $-v$ however, gives the same results as $+v$ in equations (37), (38), and (39), as it ought to do. The moment of H is the same as when the apex is uppermost, with $\frac{2}{3}\,l$ substituted for $\frac{1}{3}\,l$.

If the axis of the cone is horizontal, the same equations apply, as sufficiently explained with reference to the cylinder.

It is evident that the equations apply directly to a frustum of a cone, the convex surface of the frustum being substituted for the convex surface of the cone in the preceding equations.

II. Let us suppose the pressure upon a unit of area of surface to be, $P\cos.i=\frac{P}{\sec.\ i}$, i being the angle of incidence as before. Let us consider a hemispherical dome. Then the pressure on the band $cdec'e'$ in Fig. 1 is

$$dN=P\cos.i\,.\,\frac{\pi}{2}r^2\sin.\ i\ di=$$

$$=\tfrac{1}{2}\,P\pi\,r^2\cos.i\sin.i\ di \quad . \quad (45)$$

$$\therefore\ N=-\tfrac{1}{4}\,P\pi\,r^2\Big\{\cos.^2i\Big\}_{o}^{\frac{\pi}{2}}=$$

$$=\tfrac{1}{2}\,P\times\tfrac{1}{2}\pi r^2=.7854\ Pr^2 \quad . \quad (46)$$

On the whole dome, $2N=\frac{1}{2}P\times\pi r^2$. (47)

The average normal pressure is therefore equal to $\frac{1}{2}$ P.

TO FIND X.

From (45), $dX=dN\cos.i=$

$$\tfrac{1}{2}\,P\pi r^2\cos.^2i\sin.\ i\ di$$

$$\therefore\ X=\tfrac{1}{2}\,P\pi r^2\int\cos.^2i\sin.i\ di=-\tfrac{1}{6}$$

$$P\pi r^2\Big(\cos.^3 i\Big)_{o}^{\frac{\pi}{2}}=\tfrac{1}{6}\,P\pi r^2. \quad (48)$$

and $2X= \quad =\frac{2}{3}P\,\frac{1}{2}\pi r^2\ =\ \frac{1}{3}\,P\pi r^2$. (49)

Hence the X component of the pressure is equivalent to a pressure of $\frac{2}{3}$ P on each unit of the meridian plane YAZ.

TO FIND THE MOMENT AND THE POINT OF APPLICATION OF X.

The moment of dX about the point X is

$$dM=dX\,.\,\frac{2}{\pi}cO=d\,X\frac{2}{\pi}r\ \sin.i=$$

$$=Pr^3\cos.^2i\sin.^2i\ di. \quad (50)$$

$$\therefore M=Pr^3\int\Big(\sin.^2i\ di-\sin.^4i\ di\Big)=Pr^3$$

$$\Big\{i-\frac{\sin.i\cos.i+2\sin.^3i\cos.i}{8}\Big\}_{o}^{\frac{\pi}{2}}=$$

$$=\frac{\pi}{16}\,Pr^3. \quad (51)$$

$$\text{Now}\ \frac{M}{X}=\frac{3}{8}r=\sin.^{-1}22°1'27'' \quad . \quad . \qquad (52)$$

giving the point of application.

TO FIND THE VERTICAL COMPONENT Z.

From (45) and the equations preceding (9), the vertical component of the pressure on the band

$$=dZ=\frac{2}{\pi}\sin.i\times\tfrac{1}{2}P\pi r^2\cos.i\sin.i\,di=$$
$$=Pr^2\cos.i\sin.^2 i\,di. \qquad (53)$$

$$\therefore Z=Pr^2\int\sin.^2 i\cos.i\,di=\tfrac{1}{3}Pr^2$$
$$\left\{\sin.^3 i\right\}_0^{\frac{\pi}{2}}=\tfrac{1}{3}Pr^2. \qquad (54)$$

$$\text{and } 2Z=\tfrac{2}{3}Pr^2. \qquad (55)$$

TO FIND THE MOMENT AND THE POINT OF APPLICATION OF Z.

Moment of $dZ=dM'=dZ\cos.i=Pr^3\cos.^2 i\sin.^2 i\,di$, which is the same as (50).

Hence, $M'=\frac{\pi}{16}Pr^3$.

$$\text{and}\ \frac{M'}{Z}=\frac{3\pi}{16}r=.589r=\sin.^{-1}36°5'20''.$$

Now the resultant, $R=(X^2+2Z^2)^{1/2}$

$=Pr^2[(.5236)^2+2\,(\tfrac{1}{3})^2]=Pr^2$

$(.27415696+.22222222)^{\frac{1}{2}}=.70454Pr^2$.

Also $R'=[(2X)^2+(2Z)^2]^{\frac{1}{2}}=$

$(1.09662784+.44444444)^{\frac{1}{2}}=1.2414\,Pr^2$.

The angle between the two partial resultants is given by,

$$\cos.\,\theta=\frac{X^2}{X^2+2Z^2}=\frac{.27415696}{.49637918}=.55231$$

$\therefore\ \theta=56°28'28''$ and $\frac{\theta}{2}=28°14'14''$ the angle the partial resultants make with the plane XZ.

The pressure on the plane XZ is, therefore, R sin.

$28°14'14''=.70454Pr^2\times.47312=\frac{1}{3}$

$Pr^2=Z=Y$, as before found. (56)

From (54) and (48) we have,

$\frac{Z}{X}=\frac{2}{\pi}=.63662=\tan.\ 32°28'54''$ which is the angle the resultant makes with the plane XY.

As other results, in the light of the above, are easily found, it is not necessary to extend this part of the subject. It is probable, too, that the former results agree more nearly with experiments than the latter. The latter results are always greater than the former, as I will now show; and so probably err on the safe side.

$$\text{We have,}\ \frac{\cos i}{1}=\frac{1}{\sec.\ i}=\frac{1}{(1+\tan.^2 i)^{\frac{1}{2}}}$$

$$\text{and}\ \frac{1}{1+\frac{1}{2}\tan.^2 i}=\frac{1}{(1+\tan.^2 i+\frac{1}{4}\tan.^4 i)^{\frac{1}{2}}}.$$

We see that the above formulas meet, in general, every practical demand in reference to domes and their supports. They apply, also to the parts of bridges, including suspension cables, ropes and wires for the transmission of power, telegraph wires, etc. Also to water tanks, stand pipes, chimneys, towers, columns, etc.

The writer expects to deal still further with the general subject in a future article.

REPORTS OF ENGINEERING SOCIETIES.

ENGINEERS' CLUB OF PHILADELPHIA—RECORD OF REGULAR MEETING, October 18th, 1884. President William Ludlow in the chair. Mr. C. Henry Roney showed a Portable Storage Battery for Mining and Exploring Purposes, with small incandescent lamps, illustrating his remarks with blackboard sketches. The battery shown was a modification of Planté's, devised by Dr. E. T. Starr, of Philadelphia, the electrodes consisting of V-shaped plates of sheet lead arranged over each other, the convexity downwards, with a slight interval between them, their ends attached to a lead frame by "burned" joints, the interstices between the plates being filled with finely divided metallic lead, exposing a large surface to oxidation and reduction when subjected to dynamic electric or voltaic energy, and, in turn, giving off a large percentage of the "stored" energy to incandescent lamps placed in the circuit. The battery shown measured $3\frac{1}{4}$ inches long, $2\frac{3}{4}$ inches high, and $\frac{3}{4}$ inch thick, and would maintain a small two-candle incandescent lamp at incandescence for about one hour. A battery sufficiently large to run an eight-candle lamp for ten or twelve hours would not be too large or heavy to carry conveniently for mine or other underground exploration.

Mr. W. L. Simpson exhibited and described the Thompson Indicator. He considers it handsome in design, and convenient and simple in arrangement. Cards can be taken with it at as high a pressure as 500 lbs. per square inch. All the moving parts are made very light and strong, which is a consideration of much importance in an indicator, especially when used on engines traveling at a high rate of piston speed. The coiled spring within the paper cylinder, for increasing or decreasing the tension of different speeds of engines, is so arranged that as little or much of it can be

taken up as may be desired. This is quite an improvement, as, formerly, a whole coil of the spring had to be taken up or none at all. By means of a jamb nut the horn handle screw can be set so as to regulate the pressure of the pencil on the paper, the back of the screw touching against a small post, and thus avoiding any strain tending to throw the parts out of line through too much pressure. To exchange springs is very easy, it only being necessary to unscrew the milled nut at the top of the steam cylinder, take out the piston with its arm and connections, disconnect the lever and piston by unscrewing the small knurled-headed screw which connects them, when the spring can be removed from the piston and the desired one substituted.

All springs made for this indicator are scaled, providing for 30 inches vacuum; and the capacity of any spring can be ascertained by a simple rule. To adapt the Thompson indicator to all pressures, springs can be made to any desired scale. The following are the most generally used: 8, 10, 12, 16, 20, 24, 30, 32, 40, 48, 50, 56, 60, 64, 80, 100. For pressures from 65 to 85 lbs. a 40 lb. spring is best adapted, for as 40 lbs. pressure on a 40 lb. spring will raise pencil one inch, 85 lbs. pressure on the same spring will raise pencil about two inches, which is the usual height of a diagram.

By means of the "detent motion," consisting of a pawl and spring stop, the paper cylinder can be stopped and the card taken off without unhooking the connecting rod. An arrangement of a swivel carrying a scored wheel allows the connecting cord to be run at any angle, so that it is possible to connect with any motion, of whatever kind, wherever it may be.

Mr. J. J. deKinder described the repairs to the 36-in. Belmont Submerged main, Philadelphia, recently made by him. The specially novel feature of this undertaking was a floating cofferdam, the bottom of which was built around the main, and the whole structure kept in exact balance, during freshets, etc., by two water-tight scows, suspended on its sides, into or out of which water was pumped to regulate the weight.

The rock lay so near the river bottom as to render a sheet-pile structure impossible.

W. Bugbee Smith introduced the subject of the Fire Protection of Mills. Mills must be properly built and furnished with adequate fire extinguishing apparatus. The best construction has been found to consist of heavy wooden posts and girders, solid plank floors and roof. The usual fire extinguishing apparatus consists of water buckets, hydrants and hose. In addition to this, some mills are furnished with perforated sprinkler pipes, running lengthwise through the mill, perforated with holes $\frac{1}{10}$ inch diameter and about nine inches apart. In case of a fire, by opening a valve outside of the building, water is let into the pipes and on the fire. The objection to this system is the fact that the water is not confined to the spot where the fire occurs, but is distributed over such a large area that much damage is done by it. It also requires human agency to make it effective.

To overcome these objections, automatic sprinklers, have been invented. These are valves, placed on a system of pipes near the ceiling and opened by the heat of the fire. They are kept closed by means of a fusible solder which melts at about 160° Fahr. The heat rising from a fire melts the solder joints of the sprinkler immediately over it, and thus the water is put just where it is needed.

There are two general classes of automatic sprinklers, the sealed, such as the Parmelee, Burritt, Rose and Bishop; and the sensitive, such as the Grinnell, Burritt, Brown & Hall, and the Kane. After describing the methods of piping a mill for each of the classes, samples of the above-mentioned sprinklers were exhibited and their peculiarities explained.

The automatic sprinklers have been in use about twelve years, and recent tests show that the fusible solder has not lost its strength and sensitiveness in that length of time, though exposed to pressure and water hammer.

The effectiveness of automatic sprinklers s fire extinguishers is shown by the fact, that out of 110 fires originating under them and of which the damage is known, for 67, or 60.9 per cent. of the whole number, no damage was claimed; for 12, or 10.9 per cent,, the damage was less than $250; for 8, or 7.2 per cent., between $250 and $500; for 11 or 9.9 per cent., between $500 or $1,000; for 12, or 10.9 per cent., between $1,000 and $20,000.

The Secretary exhibited, for Mr. S. L. Smedley, a photo-lithographic reproduction of a topographical map of Philadelphia, by John Hills, 1796, and pointed out some of the remarkable evidences of its great accuracy in detail.

Mr. Francis Lightfoot, of West Chester, introduced by the Secretary, explained a model of a Rail Joint in which no plates or loose pieces are required, the ends of the rail being lapped and bolted together through oblong slots.

NOVEMBER 1st, 1884.—President William Ludlow in the chair.

The Secretary presented, for Mr. A. W. Sheafer, Notes upon the Relative Cost of Haulage in the Anthracite Mines of Penna., by Mules and Locomotives. These embodied the results of investigations by Mr. Thomas H. Phillips, Supt. Kalmia Colliery. The results are as follows: Cost per ton per mile: by locomotive, $\frac{6}{10}$ cents, by mules $1\frac{82}{100}$ cents; saving, per ton per mile by locomotive, $1\frac{22}{100}$ cents. This includes operating expenses and depreciation, but does not include the additional number of cars and turnouts and repairs to roads, required for mule service.

The Secretary also exhibited for Mr. Sheafer, a set of Electrical Photographs of the Kohinoor Colliery Mine Workings. The exposures were from 20 to 30 minutes, and the results are excellent.

The Secretary exhibited the Bush Interlocking Rail Bolts, which interlock within the tie under the middle of the rail. They are specially intended, it is believed, to resist the lateral strain of the train upon curves.

Mr. Thomas M. Cleemann continued some previous remarks that he had made on the

Strength of Wrought Iron Columns, showing how some recent experiments by Mr. James Christie, at the Pencoyd Iron Works, gave values of the constants in Rankine's formula somewhat different from those generally used, and which would, therefore, be better to adopt, for calculating their strength, in structures of American iron.

In discussing the above, Mr. James Christie stated that the experiment referred to by Mr. Cleemann were subsequently supplemented by similar experiments on steel, and a basis established for the relations existing between steel and iron compression members for structures. In addition to the practical results obtained, the experiments were of peculiar interest, inasmuch as they add additional confirmation to the ordinary theory of flexure as propounded by Euler a century ago. Experiments on beams of iron and various grades of steel, show a practically uniform elasticity, however different the materials may be in ultimate tenacity. When the lengths of column are so great in proportion to cross dimensions that failure will occur almost entirely by bending, then the elasticity of the material is the sole measure of its resistance, and the common theory of flexure will apply The experiments showed that when certain ratios of length to cross-section were reached, uniform resistance occurred between iron and steel, a fact, he believed, not heretofore known.

Capt. O. E. Michælis presented a blackboard description of what he was *allowed to see* at the recent exhibition of the "Keeley Motor" in Philadelphia.

ENGINEERING NOTES.

Construction of a Dry-Dock in Quicksand. By — Zimmermann.—This dock was built at Hamburg for the Hamburg-American Steam Packet Company. The only available site was a narrow strip on the Bank of the Elbe, perpendicular to the river, partly below high water, and the soil so loose and porous that it would only stand at a slope of 1 in 4. The excavation was 390 feet long, 66 feet broad, and about 23 feet below low-water level as a maximum.

Want of space precluded the formation of a cofferdam, of several rows of sheet piles of varying heights, which would have been the safest arrangement, so it had to be constructed of a single line of sheet-piling, which not only had to support the entire pressure of the surrounding soil, but, owing to its unavoidable imperfect watertightness, allowed the water to percolate through the sides. The first step, therefore, was the setting up of four turbines for pumping out the water. The work demanded of them was the lifting of 15,275 cubic yards, a maximum height of 23 feet in three-and-a half hours; but they did it perfectly in half that time—that is, they lifted on an average 2.42 cubic yards per second.

In order to limit the depth to which the piles had to be driven as much as possible, the bottom of the dock was not made horizontal, but rounded, to correspond with the form of a vessel, so that to drive the piles down to 23 feet below low-water level was sufficient. The space enclosed by the piling was then dredged out. The concrete employed for the foundation was formed of 9 parts Luneburg lime, 7 trass, and 16 sand, mixed with twice that volume of broken stone, and was at first shot out for the entire thickness of the floor of the dock at once, by means of a wooden shoot or funnel attached to a traveling crane; but this arrangement did not answer well, for the shoot often splintered and broke, so an iron one had to be substituted. After the concrete had lain three months under water, the water was pumped out, and the concrete, though not perfectly set, was found sufficiently water-tight. Splinters of the wooden shoot were found in the concrete floor, and their removal caused strong springs or leaks, but these were successfully stopped by iron-cement.

On the concrete floor the side and front walls were built of brickwork, and carried up to summer flood-level, with a rebate or recess for a caisson, and all round the dock is a quay-wall reaching above highest flood-level.

After a time it was observed that the butting of the caisson against the walls loosened the mortar, and the recess was not watertight, but it was made completely so by a facing of planed cast iron with concrete backing.

The weight of the empty dock alone is not sufficient to resist the upward thrust of the water at very high tides; but when loaded with the weight of a ship there is, of course, an abundant margin; and when no ship is in dock it is arranged that so much water shall be admitted as will satisfy the conditions of safety. The work was carried out in 1868 to 1870, and cost £65,000.

IRON AND STEEL NOTES.

Constituents of Steel.—At the recent meeting of the Iron and Steel Institute, Mr. I. Lowthian Bell in the discussion of a paper on crucible steel, said, some importance seemed to be attached by Mr. Seebohm to the possibility of manganese existing in possibly two forms in steel. He had made no experiment with a view of ascertaining that, but it might interest Mr. Seebohm and Mr. Snelus, who also spoke on the subject, to know that not only carbon, but, as he believed, manganese was also occasionally separated in the way that carbon was, because upon one or two occasions, noticing a species of excrescence, as it were, on the face of pig-iron run from the blast furnace, he had this matter, which was silica in appearance, analyzed, aad found it contained not only a certain portion of carbon, but a considerable quantity of manganese, and also of silica—silica in such a state of mechanical texture as left no doubt at all on his mind that, in point of fact, the silicon had been extruded from the iron itself and oxidized as it met the air, and thus formed silica. He quite agreed with what fell from Mr. Seebohm as to the desirability of the chemist being appealed to, perhaps even more urgently than he had yet been appealed to, with regard to explaining certain differences in the quality of steel, and, indeed of iron, generally. If the chemist up to that time had not succeed-

ed in furnishing an explanation for all those differences, gentlemen must remember that the science of chemistry as applied to iron, certainly in this country, was somewhat new, and that the quantity of matter necessarily very seriously affecting the quality of the steel was so minute that they could scarcely be surprised if the researches of chemists had not yet mastered with sufficient exactness all the details required for ascertaining and detecting the presence of matter in such small quantities as were required for effecting the object he had just referred to. He might state that only recently, at the Monkbridge Iron-works, they were making iron, and they found it to be very red short. Mr. Kitson sent a specimen to him in order that he might ascertain if possible, the cause of this. Believing it possible that occluded oxygen might be at the root of the evil, he had some experiments tried upon the old lines, and found nothing to induce him to believe that oxygen was at the root of the evil; but happening to fall upon a recently discovered method of estimating the quantity of oxygen in iron, he had that tried, and then he found that in the red short iron there was fully double the quantity of oxygen in some form or another than there was in the specimens that were not red short. He merely mentioned this circumstance to show that they must not be impatient, but must work diligently and carefully in order to make themselves properly acquainted with all the circumstances and conditions which affected the quality of the material in the manufacture of which they had so great an interest.

RAILWAY NOTES.

French Railway Rolling-Stock.—There are altogether, on French railways, 6,893 locomotives, of which 2,826 are passenger, and 4,067 goods engines. There are also 15,432 carriages, of which 3,208 are first-class, 5,315 second-class, and 6,909 third-class, together with 182,089 wagons. As regards the principal companies, the following are the figures: Northern, 1,138 locomotives, 2,021 carriages, and 33,971 wagons; Eastern, 922 locomotives, 2,359 carriages, and 22,401 wagons; Western, 1,045 locomotives, 2,881 carriages, and 17,465 wagons; Orleans, 970 locomotives, 2,100 carriages, and 40,433 wagons; Paris-Lyons-Mediterranean 1,960 locomotives, 3,489 carriages, and 62,200 wagons.

ORDNANCE AND NAVAL.

The Heavy Guns of 1884.—This formed the subject of a lecture delivered by Colonel E. Maitland, R.A., superintendent of the Gun Factory, Woolwich, before the United Service Institution, on June 20. The walls of the theater were covered with diagrams of the latest piece of ordnance and sections of breeches, whilst the floor was occupied by a steel cannon and the breech of one of the new pattern interrupted screw breechloading guns Colonel Maitland said this was the time for laying before the public as clear an exposition as possible of the subject, which was one of national importance, setting forth the causes which had led to the necessity for the re-armament of our naval and military forces, the progress now made in that re-armament, and the comparative efficiency of the heavy guns of 1884 in England and in the other chief countries of the world. The chief causes which had led to the necessity for the changes in our armament were—first, the improvement in powder; secondly, the improvement in mechanical appliances; and, thirdly, the improvement in production of large masses of steel. These considerations had affected the great continnetal powers, for they also were re-arming extensively, though the changes being made on the Continent were more gradual and less radical than our own. In the latter part of the seventies (the period between 1869 and 1880) England certainly fell behind in the artillery race, but not to the extent supposed by many who had not studied the subject. As a matter of fact the old short breechloaders of the Continent were just as obsolete now as the old short muzzle-loaders of England, and up to 1875 or 1876 the British artillery was as good as anybody else's. Then came a period of stagnation, and we fell to leeward. This country, however, had not been caught napping by an important war, but in waiting had got the best of the artillery contest. Colonel Maitland then, for the information of non-artillerists, dealt with some of the technicalities of the gunner's craft, and explained the improvements which had occurred in the making of gunpowder, one improvement being an increased energy given to the projectile by the slowing of the powder, so that it should burn while the projectile was traversing the bore and increase in burning until the projectile was about to leave the muzzle. He discussed the important question of powder at length, and showed that the improvements in it had rendered breechloading in the guns to be an absolute necessity, as the guns had now to be made so long that loading from the muzzle became practically impossible on service, and the projectile had to be held fast until a pressure of from 1 ton to 2 tons per square inch was set up in the chamber, which could only be done in breech-loading guns. He spoke warmly of the promptitude with which Colonel Brackenbury, of the Woolwich Gunpowder Factory, had grappled with the difficulties of giving a suitable powder for improved English guns. Having referred to the cocoa powder of the Germans—a secret—Colonel Maitland dealt with the subject of breechloading and remarked that a satisfactory closing of the breech was not accomplished by any nation until after the Franco-German war of 1870-71, after which period Krupp entirely remodeled his breech fittings, and the French adopted an entirely new method of obturation, invented by Dr. Bange, of the French artillery. Colonel Maitland then stated that we had in hand guns of an efficient character up to 110 tons. He next spoke upon the Krupp system, the French marine system, the French land service system, and, lastly, upon the improvements which had been adopted in some of our own guns, the trials of these systems, and the avoidance of some defects discovered in working. He presented a section of the Elswick gun of 110 tons, being manufac-

tured for the government by Sir W. Armstrong, Mitchell & Co. This gun, he said, was entirely of steel, and had three layers of hoops over the breech-piece. In this gun there would be several important improvements upon the 100-ton gun of the Italian government. As to the adoption of steel for breechloaders, he justified the adoption of the metal, now thoroughly tested by German experience, and declared that England, in coming last, had really got the best forged steel construction known in guns. He considered that England had obtained all the advantages of France and Germany combined, and, moreover, not being hampered by the necessity of utilizing old material, we had been able to devote all our energies to new guns of the best quality, instead of altering old guns of inferior type. We had, moreover, greatly extended the ballistics of our guns, and had conferred on them unsurpassed powers in proportion to their weight. In conclusion, he said that now the time had arrived for the country to face the question of re-armament seriously, to grant the money, and to push on the manufacture. After remarks made by several speakers upon different points in the lecture, the discussion was adjourned.

The Torpedo Fittings of the Navy.—In the ships of war recently built and in those now in course of construction, the fitting of underwater torpedo gear has been abandoned, the experience derived from the practice of the *Inflexible* not having been altogether satisfactory. Ships designed for exclusively torpedo service, such as the *Vesuvius*, the *Polyphemus*, and the *Scout* (which is now being built on the Clyde) may continue to be provided with submerged projectiles, but even in these the torpedoes will probably be only discharged from the stem ports in consequence of the difficulty of expelling them from the broadside of a ship under way and the impossibility of firing them in a straight line. The best results have hitherto been obtained from the stem tubes, and from the great accession of speed which has been realized by the improved Whiteheads and the greater impulse which is communicated to them by the general adoption of the air-gun system, there is now no longer any danger to be apprehended from the projectile being overtaken and exploded by the ship from which it has been discharged. This desirable direct ahead fire has up to the present time been secured by two methods. In the Polyphemus, for instance, as in the similar case of the Italian turret-ship Duilio, the torpedo port is cut in the ram itself. This system has the obvious disadvantage of seriously weakening the spur and its attachments, and thus conducing to the crippling of the ship if not to its actual disablement. Provided a fair blow be delivered by the ram there will be no necessity to discharge a torpedo simultaneously with the blow to secure the complete destruction of an enemy; but should the blow, as happened in the case of the Defence and the Valiant, be deflected by a change of helm on the part of the enemy, the probability is that the spur of the Polyphemus would be so far disabled as not only to prevent her ramming a second time, but to prevent her using her torpedo armament. In the Inflexible, on the other hand, direct ahead fire is obtained by launching the torpedo over the stem by a sliding bar from above, a method which exposes the mechanism and the men handling it to the torpedo guns of an enemy. A new arrangement is now being introduced into the Camperdown, building at Portsmouth, and will also be embodied in the Scout and the Benbow. In addition to the four socket tubes on the broadside having a range of 70 degrees before and abaft the beam, or 20 degrees in a fore and aft line, the Camperdown is having a torpedo port worked in her brass stem on a level with the main deck and consequently high above the water line and her submerged prow. The gear and the men will consequently be well under cover. The torpedo, which is 16 feet long and 14 inches in diameter, is inserted in a steel cylinder of just sufficient dimensions to contain the projectile, and having a brass lining in which the grooves along which the T pieces of the torpedoes run are cut. The highly compressed air is admitted at the rear of the tube and in direct contact with the torpedo. In the old system the impulse was given by means of a piston, the blow from which when the engine was not in touch with it, was sometimes violent enough to injure the delicate mechanism of the torpedo. When everything is ready for firing, a touch of the firing key releases a brass ball magnetically held in position, the fall of which is made to rotate a lever, which in its turn releases the safety pin, and the torpedo is blown out of the ship. The only mishap which could possibly attend this method is the discharge of the torpedo before the port door had been opened, and the consequent explosion of the missile on board. This might be supposed to be an imaginary danger, but it has been practically provided against by an arrangement of levers. The port itself is elliptical, to allow for the fall of the torpedo in escaping from the ship; but the true nature of the parabola described by the torpedo in falling remains to be determined by careful observations. As the projectile leaves the tube a stud trips the trigger and sets the propelling engines in motion. —*London Times.*

BOOK NOTICES

Publications Received.

Report of the Commissioner of Education for the year 1882–83. Washington Government Printing Office.

Annual Report of the Chief of Engineers, United States Army. 1884.

Monthly Weather Review for September. Washington Signal Office.

Hydraulic Tables. Compiled by John W. Hill, M.E. Cincinnati: Robt. Clarke & Co.

House Drainage as Constructed by the Durham House Drainage Co. By Wm. Paul Gerhard. New York: D. Van Nostrand. Price 50 cents boards, $1.00 cloth.

Proceedings of the United States Naval Institute. Vol. X. The Establishment of Steel Gun Factories in the United States. By Lieut. W. H. Jaques, U. S. N. Annapolis, Md.: Naval institute.

The subject of this volume is of deep interest to many. The author has aimed to show the necessity for the manufacture of steel guns in this country, and to provide a manual of reference for those who desire to know the details of the latest methods of manufacture.

The methods pursued in England, France, Germany, Russia and United States are described and fully illustrated by diagrams.

An enumeration of the machines and tools for a plant for gun manufacture, and the "General Summary of the Gun Foundry Board" close the volume.

A Treatise on the Adjustment of Observations. By T. W. Wright, B.A., late Assistant Engineer, United States Lake Survey. New York: D. Van Nostrand.

The method of obtaining the most reliable result from a series of observations or measurements, when such observations are multiplied for the sole purpose of securing accuracy, is a subject of profound study, which is alike profitable to the student of theory or to the practical worker. The author of the present treatise is fully in sympathy with both classes, and, moreover, exhibits the capabilities of an instructor.

The increasing demand for better accuracy in surveys of all kinds has been responded to by the production of better instruments. But given the best instruments and the best observers, the question of how to obtain the best results is still an open one. To the importance of this question, the attention of American students has not been heretofore sufficiently awakened. This treatise will be found to be a valuable stimulus to learners who aspire to the performance of good work in Surveying, Astronomy or Physics.

The introductory chapter fully sets forth the nature of the work to be accomplished, viz.: the elimination of the effects of errors in measurements of various kinds, and describes the sources and kinds of error whether inherent or accidental in either the observer or instrument, or external to both as in the atmospheric conditions; and summarizes the conditions as follows: "When all known corrections for instrument, for external conditions, and for peculiarities of the observer have been applied to a direct measure, have we obtained a correct value of the quantity measured? That we cannot say. If the observation is repeated a number of times with equal care different results will in general be obtained.

The reason why the different measures may be expected to disagree with one another has been indicated in the preceding changes. There may have been no change in the conditions of sufficient importance to have attracted the observer's attention when making the observations, but he may have handled the instrument differently, turned certain screws with a more or less delicate touch, and the external conditions may have been different. What the real disturbing causes were he has no means of knowing fully. If he had he would correct for them, and so bring the measures into accordance. Infinite knowledge alone could do this. With our limited powers we must expect a residuum of error in our best executed measures, and, instead of certainty in our results, look only for probability.

The discrepancies from the true value due to these unexplained disturbing causes we call *errors*. These errors are *accidental*, being wholly beyond all our efforts to control. As soon as they are known to be *constant*, or we learn the law of their operation, they cease to be classed as errors.

A very troublesome source of discrepancies in measured values arises from *mistakes* made by the observer in reading his instrument or recording his readings. Mistakes from imperfect hearing, from transposition of figures, and from writing one figure when another is intended, from mistaking one figure on a graduated scale for another, as 7 for 9, 3 for 8, etc., are not uncommon. These also must be classed as accidental errors, theoretically at least. Having, therefore, taken all possible precautions in making the observation, and applied all known corrections to the observed values, the resulting values which we shall in future refer to as *observed values* may be assumed to contain all accidental errors. We are then brought face to face with the question, "How shall the value of the quantity sought be found from these different observed values?"

This is followed by a brief synopsis of the mathematical principles involved in the treatise: Probabilities, Definite Integrals, Taylor's Theorem, Interpolation, and Periodic Series. This synopsis is only just full enough to inform the reader in advance of the stock of mathematical knowledge requisite for the mastery of the treatise. It is only intended to remind, not to instruct him.

The second chapter deals with the Law of Error, and we believe will be found full of interest to the mathematical student. The author shows how the accepted methods were evolved, and presents the earlier processes in historical order.

The chief topics of this chapter are: The Arithmetical Mean; Law of Error of a Single Observed Quantity; Law of Error of a Linear Function of Independently Observed Quantities; Comparison of the Accuracy of Different Series of Observations; The Probability Curve; The Law of Error Applied to an Actual Series of Observations; Classification of Observations.

There is an important appendix to this chapter at the end of the volume.

Chapter III. treats of the adjustment of Direct Observations of One Unknown Quantity. The principal topics are: Observed Values of Equal Quality; Observed Values of Different Quality; Observed Values, Multiples of Unknown; Precision of a Linear Function of Independently Observed Values.

This chapter contains a large number of examples of "Mean Square" and "Probable Error." Also two appended notes relating respectively to Weighting of Observations and Rejection of Observations. In this latter note we find the following remark regarding a *criterion* for rejection, with which we believe all practical workers will find themselves in accord.

"It may be stated, as a general rule, that criterions are apt to be most highly esteemed by those who look at the observations from a purely mathematical rather than from a practical observer's point of view. The latter is, without doubt, the true standpoint. Every observer will consciously or unconsciously construct a criterion suited to the sort of work he is engaged in. This criterion will not necessarily be founded altogether on mathematical formulas. Indeed, most likely it will not be. Nor does it follow that the criterion adopted in any special series is of universal application or will receive universal assent. In the process of weighting, the observer will not assign weights always as the inverse squares of the "mean square error." It is often better to assign them arbitrarily, from a feeling founded on a general grasp of all the circumstances connected with the making of the observations. In like manner, and in this same feeling, he will found his criterion for rejection. There is no uniform rule for weighting; neither is there one for rejection."

Chapter IV., on Adjustment of Indirect Observations, deals at much length with Determination of Most Probable Values. This is followed by: Precision of the Most Probable (Adjusted) Values; Precision of any Function of the Adjusted Values; Average Value of the Ratio of the Weight of an Observed Value to its Adjusted Value and Artifices of Elimination.

The theoretical part of the treatise is completed in Chapter V., which presents the consideration of the adjustment of a series of observations which are not entirely independent of each other. This is termed the Adjustment of Conditional Observations. A general statement of the character of the problem is followed by: The Direct Solution (Independent Unknowns); The Indirect Solution (Method of Correlates); Solution in Two Groups; Solution by Successive Approximations.

Examples are interspersed as in the preceding chapters.

The remaining portion, nearly half of the volume, exhibits applications of the principles elucidated in the foregoing chapters. The examples are mostly from American practice. They are divided as follows:

Chapter VI., Triangulation; Chapter VII., Base Line Measurements; Chapter VIII., Leveling; Chapter IX., Graduation of Line Measures, and Calibration of Thermometers; Chapter X., Empirical Formulas and Interpolation.

The work throughout exhibits signs of careful preparation, and we believe it will be regarded as a very valuable contribution to English scientific literature.

Forestry in the Mining Districts of the Ural Mountains. Compiled by John Croumbie Brown, LL. D. London: Simpkin, Marshall & Co.

This work, like the later ones of this industrious writer, is carefully compiled from reliable sources and is exceedingly compact.

The chapters present in order the following subjects: Journey from St. Petersburg; Forest Exploitation in Ufa; Mishaps in Traveling; Russia and her People; The Ural Mountains; Metallurgy; Forests; Depressed Condition of Mining and Manufacturing; Forest Exploitation; Abuses in Exploitation of Forests; Occasion of Diminished Supply of Wood; Glimpses of Life; Laboring Population: The Conquest of Siberia.

A Course of Qualitative Chemical Analysis. By W. Geo. Valentin, F.C.S. Revised by W. R. Hodgkinson, Ph. D. Sixth Edition. Philadelphia: P. Blakiston, Son & Co.

The merits of Valentin's work are well known to workers in the laboratory. The notation is that of Frankland, while the methods of separation are largely original with the author and editors.

Students using the text as a guide to practical analysis, find the full directions for their work especially convenient.

The examination questions which are appended to each section, serve to direct the learner's attention to the more salient points. Some advantage to the student is also afforded by occasionally presenting the graphic symbol of a compound.

The work is particularly good in the matter of detection of the acids and in the reactions of the rare metals. The latter portion representing the later additions to the book.

The Steam Engine Indicator and Its Use. By William Barnet LeVan. New York: D. Van Nostrand.

The literature of the indicator is by no means scanty. There are not wanting essays upon this instrument which treat, more or less lucidly, upon its peculiarities, but many of them presuppose a certain familiarity with the indicator upon the part of the student, and plunge, *in medias res*, on the first pages. In regard to the indicator itself, a revival is in progress. A class whom it is very essential to educate have taken it up and are availing themselves of its offices. They know nothing of it beyond the fact of its existence and are exceedingly anxious to learn. It is manifest that, for such readers, the treatment should be severely simple and rudimentary. It is difficult for many writers, who essay the task of teaching beginners, to comprehend this, this after brief allusions to the object of the indicator they proceed, without loss of time, to thermal units and adiabatic curves. Moreover, many works on the indicator are useless to students by reason of the mathematical processes of elucidation employed. It is natural that an expert should couch his expressions in the shortest and most concise terms, but this cuts off a great many from availing themselves of the instruction given, for reasons sufficiently obvious to require no pointing out.

In *The Steam Indicator and Its Use*, by Wm. Barnet LeVan, provision has been made for the class mentioned before. They are specially addressed, in point of fact, in simple language and by plain diagrams. Starting with a detailed description of the indicator, the author proceeds by easy stages to simple diagrams, explaining in terse language how they are produced, the best methods of taking them, and

lastly, how to compute the areas enclosed. All this is accompanied by the necessary diagrams, so that any person who is fit to be about an engine at all can use the indicator practically.

Another point in favor of the work for those for whom it is compiled, is its low price. It is issued from the press of D. Van Nostrand & Co., in their admirable Science Series, a form which has rendered many valuable papers popular, and insured a reading for scientific treatises, taken from high class publications which the multitude would never see. This work on the Indicator is appreciated by those for whom it is written, and is selling well.

Analytic Mechanics. By E. A. Bowser, Prof. of Mathematics and Engineering, Rutgers College, New Brunswick, N.J.; D. Van Nostrand, Publisher. 12mo. cloth. Price, $3.00.

An American text-book on Mechanics that would present its leading principles in a clear and simple way, and at the same time furnish a substantial preparation for its higher branches, has long been desired. The increasing applications of this branch of mathematics to the practical problems of engineering and architecture have made a knowledge of it necessary to success in these departments. No one can appreciate the advances made in the theories of Light, Heat and Electricity, who is not familiar with the methods of Dynamics.

The text-book of Prof. Bowser is admirably fitted for filling these conditions. He has succeeded in happily combining simplicity and clearness of treatment with a full exposition of some of the more difficult parts of the science.

The practical bearings of the principles are illustrated by their applications to the mechanical powers, while attention has been given to the requirements for a preliminary training in celestial and physical mechanics. The work involves the use of Analytic Geometry and the Calculus, and in itself is a valuable discipline in these branches of mathematics.

The chapters on "Moment of Inertia" and "Center of Gravity," furnish a fine illustration of the use and power of the calculus. The practical way in which the author passes from theoretical formulæ by means of numerous and wisely selected examples, to actual cases requiring arithmetical calculation, is a marked and valuable feature of the book, and makes an otherwise difficult subject, attainable and useful.

The chapter on Friction goes a great way toward divesting many of the problems of mechanics of their usually unreal character, in giving methods for dealing with the cases of bodies not perfectly smooth—cases of occurrence in things as we find them.

An entire chapter has been devoted to "Work and Energy," and these important terms are fully explained and their physical significance definitely pointed out.

Prof. Bowser has made a separate division of Kinematics—a science which bears the same relation to Dynamics that the science of Mechanism does to Mechanical Engineering.

The distinction between motion, regarded merely as change of place, and motion as produced by force has long been recognized, but seldom finds its way into our text-books. A large number of dynamical problems rest mainly on the relations between velocities, accelerations, &c., considered without reference to their causes, and there is a gain in clearness in making their treatment a separate part of the subject.

Under Kinetics the motions of bodies under the action of forces have been considered. The problems of central forces are taken up and illustrated, by showing that the Laws of Kepler are a necessary consequence of the law of gravitation.

A suggestive and instructive feature of the book is the many references to the standard works on the different branches of mechanics.

The treatment throughout is plain, direct and complete, and the arrangement is nicely adapted to purposes of instruction.

The book is of convenient size, neatly bound, and printed in clear type.

MISCELLANEOUS.

On the Measurement of Wind-Pressure—Incompleteness of Borda's Formula.—By Dr. Fines.—Borda's formula for defining pressure of wind from velocity is $F = C \times SV^2$, C being a constant coefficient for a certain plate, S the surface in square meters, V the velocity of the wind in meters per second, F the pressure of the wind in kilograms per square meter. C varies with size and shape of plate. Borda gives the following values:

C=0.092 kilo.	for plain	plates of	0.011664	sq. me.
0.100	"	"	0.026244	"
0.104	"	"	0.059049	"
0.120	"	"	0.929000	"

The first three of the above values are given by Borda, the last by Rousse. Later, Navier found that in the case of movement in the atmosphere at 10° Centigrade, under the normal pressure C=0.1278. Thibault, however, found the value of C under the same conditions to be 0.1151. Dupré considered that Navier's formula, $R = 0.1278\ SV^2$, is the right one to use.

The author states that Borda's formula gives rise to two sources of error, one owing to inaccuracy in the formula, the other to its application. Though the size and shape of the plate are known, the reciprocal reactions of the different currents of air one upon the other are not; neither are their absolute velocities, the mean velocity only is known.

The ordinary anemometer is incapable of recording the velocity of the wind at the time (of only a few seconds' duration) of the most violent gusts. M. Renard, however, made observations during the violent storm of November 16, 1880. He found that during an interval of twenty-five seconds the velocity increased from 38 to 51 meters per second, and then diminished in the following twenty seconds to 35.70 meters, so that during this short interval the pressure varied from 325 to 136 kilograms per square meter. These observations, however, do not give the absolute maximum intensity which can have lasted only a few seconds, and may have been much higher than that above stated, and it is the absolute maximum velocity which is required for an exact application of Borda's formula.—*Abstracts of Institution of Civil Engineers.*

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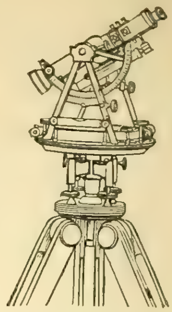

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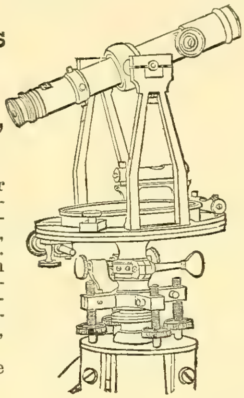

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CONTENTS.

APPENDIX.

REVISER'S NOTE.

Grateful acknowledgments are due to those whose contributions to the text have enhanced the value of this work.

Commander F. B. McNair has permitted the use of his pamphlet on Seamanship Drills.

The chapter on the Laws of Storms is taken principally from the lecture of Lieutenant-Commander Thomas Nelson, vol. 5. Proceedings U. S. Naval Institute.

Chapter XIX. is practically a reprint of Lieutenant D. Delehanty's pamphlet: "Cadet Midshipman's Manual."

Chapter XXXV. has been prepared from notes furnished by Lieutenant-Commander Z. L. Tanner, together with data from the lectures of Constructor R. H. White, R.N., and from the professional pamphlets of the German Admiralty on steamers and screw propulsion.

The suggestions made by boatswain Robert Anderson, U.S.N., have been of special importance. Getting a lower yard on board, sending down a lower yard inside of rigging, rigging derricks, and carrying out anchors between two cutters in shoal water, are described from actual work performed under his direction.

To Commander Taylor, Lieutenants Berry, Nazro and Holman, U.S.N., and to many other officers, sincere thanks are tendered for their assistance and suggestions in the revision of the proofs.

AARON WARD, *Lieutenant, U. S. N.*

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The July number commences the Thirty-first Volume of this Magazine. The Publisher would state that the support accorded to it, from its commencement, by the educated engineers of the country, to whom, of course, it largely appeals, has not been such as to either encourage him for the future, or to warrant the continuance of its publication. At the same time he may add that he never had any desire or intention to permit the Magazine to recede from the high position it made for itself from the start, and has preferred continuing it at a financial loss, rather than allow it to assume an attitude different from what it has always had. The continuance of its publication will depend, therefore, very much upon its support for the present year. If our educated engineers can afford to permit its discontinuance from lack of adequate support, the Publisher certainly can afford to do so, to his advantage, believing he has discharged his duty in the efforts he has made in the past toward establishing an able and perfectly unpartisan medium through which authoritative writers on scientific subjects, both technical and practical, could best present original essays to American readers, as well as affording a Magazine, in which the best current Engineering literature from the leading foreign journals could be reproduced.

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